METALLIFEROUS LODES IN SOUTHERN SEWARD PENINSULA.

By S. H. Cathcart.

INTRODUCTION.

The value of the total mineral output of Seward Peninsula is about $81,000,000, of which over $80,000,000 is the value of the gold won from placer mines. Lode prospecting began soon after placer mines were developed[1] and has been continued in a more or less desultory manner through a period of 20 years, but thus far the attempts to open up lode mines have met with but little success. Little bedrock work has been done since 1917, when the effects of the World War began to be felt, and since then the suspension of the requirement for annual assessment work has still further decreased the prospecting of lode claims. In 1915 and 1916, owing to the war demands, a temporary stimulus was given to the mining of stibnite-bearing lodes, but it soon subsided. The Big Hurrah quartz mine is the only lode-gold producer that was opened up on any considerable scale, and this mine was operated only from 1903 to 1908 and then not continuously. Within the last few years underground work has been done at the Lost River tin mine, the Kougarok silver-lead property, and the gold lodes near Bluff, but elsewhere lode development has been almost negligible. There are now no productive lode mines in the region under discussion; only a few have produced in the past, and the output from those few has been small.

In the area of the York Mountains the relation of the mineralization to the geology has been pretty well established.[2] Tin, tungsten, antimony, copper, and lead have been discovered and are known to be closely related to granite bosses and porphyry dikes that intrude the limestone and slates. For the rest of the peninsula no such relation has been determined. A possible exception is the platinum recovered from the placers of Dime Creek. Basic igneous rocks occur in the vicinity of these placers, and although platinum has not been determined as a constituent of those rocks it is believed to have been derived from them.

In the absence of such well-defined genetic relations for the mineralization of most of the peninsula, it was deemed desirable to ascer-

[1] An exception to this statement is the silver-lead deposit at Omalik in the Fish River basin, which was opened up and from which some ore was shipped as early as 1881.

[2] Steidtmann, Edward, and Cathcart, S. H., The geology of the York tin deposits, Alaska: U. S. Geol. Survey Bull. — (in preparation).

tain the conditions which have led to a very wide distribution of metallic minerals throughout the country rock, especially the conditions which have resulted in concentrations of gold rich enough to be reflected in scattered placer deposits but which have not produced gold lodes of notable promise.

The writer undertook to determine, so far as the physical conditions permitted, the geologic relations of the bedrock occurrence of metallic minerals in this region. It was believed that such studies might help the prospector by determining the geologic conditions under which the metalliferous lodes were formed. Field work was begun on July 3 and continued until September 19, 1920. During this time most of the lodes of the peninsula in the area south of the mountains, between Council on the east and Cripple River on the west, were visited and the country rock in the vicinity of the richest placers was studied in an attempt to determine something more concerning the relations that exist between the mineralization of the region and the geology. In all 110 prospects were examined, and the ores, where available, were studied. The prospects show considerable variety in mineralization. Iron, bismuth, tungsten, gold, copper, lead, zinc, graphite, and antimony have been found in bedrock, and mercury is known in the placers.

The investigation was originally planned to be continued through several years, with the hope of not only determining the genesis of the ores but also correlating the many geologic formations found in Seward Peninsula. As for the present the investigation has been suspended, it seems desirable to record the provisional conclusions reached during the first season of field work.

This paper outlines certain features of the mineralization that were observed. It does not describe in detail all the prospects examined, nor discuss in more than a general way the mineralization of other important districts which were not visited. Descriptions of the geology and mineral deposits of the peninsula are contained in previous reports published by the United States Geological Survey, a list of which follows.

Preliminary report on the Cape Nome gold region, Alaska, with maps and illustrations, by F. C. Schrader and A. H. Brooks: Special Pub., 56 pp., 19 pls., 1900.

Reconnaissance in the Cape Nome and Norton Bay regions, Alaska, in 1900 (A reconnaisance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900, by A. H. Brooks, assisted by G. B. Richardson and A. J. Collier; A reconnaissance in the Norton Bay region, Alaska, in 1900, by W. C. Mendenhall): Special Pub., 222 pp., 23 pls., 1901.

An occurrence of stream tin in the York region, Alaska, by A. H. Brooks: Mineral Resources, 1901, pp. 267-271, 1902.

A reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier: Prof. Paper 2, 70 pp., 12 pls., 1902.

Stream tin in Alaska, by A. H. Brooks: Bull. 213, pp. 92-93, 1903.

The Kotzebue gold field of Seward Peninsula, Alaska, by F. H. Moffit: Bull. 225, pp. 74–80, 1904.

Tin deposits of the York region, Alaska, by A. J. Collier: Idem, pp. 154–167.

The tin deposits of the York region, Alaska, by A. J. Collier: Bull. 229, 61 pp., 7 pls., 1904.

The Fairhaven gold placers, Seward Peninsula, Alaska, by F. H. Moffit: Bull. 247, 85 pp., 1905.

Recent development of Alaskan tin deposits, by A. J. Collier: Bull. 259, pp. 120–127, 1905.

Gold mining on Seward Peninsula, by F. H. Moffit: Bull. 284, pp. 132–144, 1906.

The York tin region, by F. L. Hess: Idem, pp. 145–157.

The Nome region, by F. H. Moffit: Bull. 315, pp. 126–145, 1907.

Gold fields of Solomon and Niukluk river basins, by P. S. Smith: Bull. 314, pp. 146–156, 1907.

Geology and mineral resources of Iron Creek, by P. S. Smith: Idem, pp. 157–163.

The Kougarok region, by A. H. Brooks: Idem, pp. 164–181.

Water supply of Nome region, Seward Peninsula, 1906, by J. C. Hoyt and F. F. Henshaw: Idem, pp. 182–186.

The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarok, Port Clarence, and Good Hope precincts, by A. J. Collier, F. L. Hess, P. S. Smith, and A. H. Brooks: Bull. 328, 343 pp., 1908.

Water-supply investigations in Alaska, 1906–1907 (Nome and Kougarok regions, Seward Peninsula, etc.) by F. F. Henshaw and C. C. Covert: Water-Supply Paper 218, 156 pp., 2 pls., 1908.

Investigation of mineral deposits of Seward Peninsula, by P. S. Smith: Bull. 345, pp. 206–250, 1908.

The Seward Peninsula tin deposits, by Adolph Knopf: Idem, pp. 251–267.

The mineral resources of the Lost River and Brooks Mountain region, Seward Peninsula, by Adolph Knopf: Idem, pp. 268–271.

Water supply of the Nome and Kougarok regions, Seward Peninsula, 1906–1907, by F. F. Henshaw: Idem, pp. 272–285.

Geology of the Seward Peninsula tin deposits, Alaska, by Adolph Knopf: Bull. 358, 71 pp., 9 pls., 1908.

Recent developments on Seward Peninsula, by P. S. Smith: Bull. 379, pp. 267–301, 1909.

The Iron Creek region, by P. S. Smith: Idem, pp. 306–354.

Mining in the Fairhaven Precinct, by F. F. Henshaw: Idem, pp. 355–369.

Water-supply investigations in Seward Peninsula, 1908, by F. F. Henshaw: Idem, pp. 370–401.

Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska, by P. S. Smith: Bull. 433, 234 pp., 16 pls., 1910.

Mining in Seward Peninsula, by F. F. Henshaw: Bull. 442, pp. 353–371, 1910.

Water-supply investigations in Seward Peninsula in 1909, by F. F. Henshaw: Idem, pp. 372–418.

A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska, by P. S. Smith and H. M. Eakin: Bull. 449, 146 pp., 13 pls., 1911.

Geologic features of Alaskan metalliferous lodes, by A. H. Brooks: Bull. 480, pp. 43–94, 1911.

Notes on mining in Seward Peninsula, by P. S. Smith: Bull. 520, pp. 339–344, 1912.

Geology of the Nome and Grand Central quadrangles, Alaska, by F. H. Moffit: Bull. 533, 140 pp., 12 pls., 1913.

Surface-water supply of Seward Peninsula, Alaska, by F. F. Henshaw and G. L. Parker, with a sketch of the geography and geology by P. S. Smith and a description

of the methods of placer mining by A. H. Brooks: Water-Supply Paper 314, 317 pp., 1913.

Placer mining on Seward Peninsula, by Theodore Chapin: Bull. 592, pp. 385–395, 1914.

Lode developments on Seward Peninsula, by Theodore Chapin: Idem, pp. 397–407.

Iron ore deposits near Nome, by H. M. Eakin: Bull. 622, pp. 361–365, 1915.

Placer mining in Seward Peninsula, by H. M. Eakin: Idem, pp. 366–373.

Antimony deposits of Alaska, by A. H. Brooks: Bull. 649, 67 pp., 3 pls., 1916.

Lode mining and prospecting on Seward Peninsula, by J. B. Mertie, jr.: Bull. 662, pp. 425–449, 1917.

Placer mining on Seward Peninsula, by J. B. Mertie, jr.: Idem, pp. 451–458.

Mineral springs of Alaska, by G. A. Waring, with a chapter on the chemical character of some surface waters of Alaska, by R. B. Dole and A. A. Chambers: Water-Supply Paper 418, 118 pp., 9 pls., 1917.

Mineral resources of Seward Peninsula, by G. L. Harrington: Bull. 692, pp. 353–400, 1919.

Mining in northwestern Alaska, by S. H. Cathcart: Bull. 712, pp. 185–198, 1920.

Pliocene and Pleistocene fossils from the Arctic coast of Alaska and the auriferous beaches of Nome, Norton Sound, Alaska, by W. H. Dall: Prof. Paper 125, pp. 23–37. pls. 5–6, 1919.

Geology of the York tin deposits, Alaska, by Edward Steidtmann and S. H. Cathcart (in preparation).

GEOLOGY.

OUTLINE.

The foregoing list of publications indicates the large number of geologic investigations that have been made on Seward Peninsula. The Geological Survey has published reconnaissance geologic maps (scale 1:250,000) of nearly the entire region (20,000 square miles) and detailed maps (scale 1:62,500) of certain important districts.[3] These surveys and investigations have been made by a score of geologists during a period of more than 20 years. Each new investigation has added many additional facts bearing on the geology and the occurrence of mineral deposits. As yet there has been no adequate summary of this large mass of material and no correlation of the many formations to which the rocks have been assigned. To the end that a better understanding may be had of the relation between the ore deposits, to be here described, and the general geology of the region, the following provisional statement on the stratigraphy of Seward Peninsula as a whole is here quoted from an unpublished manuscript by A. H. Brooks:

The bedrock of Seward Peninsula includes many sedimentary formations, ranging in age from pre-Ordovician to middle Carboniferous (Pennsylvanian). There are also some Upper Cretaceous sediments, as well as extensive lava sheets, chiefly of Quaternary age but in part possibly older, in the eastern part of the peninsula. In much the larger part of the peninsula intrusive rocks are not abundant, but in the Kigluaik, Bendeleben, and Darby mountains there are extensive stocks of granite rocks with

[3] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 433, pls. 6–7, 1910. Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, pls. 3–4, 1913.

some dikes. There are also a number of granitic stocks, with which porphyry dikes are associated, in the York district. A few isolated stocks of granite occur in other parts of the peninsula. There are also local occurrences of pegmatitic, gabbroid, and diabasic intrusives.

All investigators of this field have recognized two distinct systems of structure, one trending about north and the other about east, but there is diversity of opinion as to which is the older. The Cretaceous rocks of the eastern part of the field are involved in the northerly folds. As these are the youngest consolidated rocks, it is evident that their deformation occurred during the most recent period of crustal disturbance. There is, however, some evidence of folding in late Paleozoic time, which produced structural features trending north. It is therefore possible that the post-Cretaceous (Eocene?) folds followed the structure of older Paleozoic time. The east-west folding is probably to be correlated with the dominating structural features of the Arctic Mountain system of northern Alaska and Siberia, which trend approximately east. This folding was certainly earlier than Upper Cretaceous, probably pre-Cretaceous, and certainly not earlier than Middle Jurassic. There is evidence that there has also been some later movements along these older east-west folds. As the intrusions were no doubt in a general way contemporaneous with the folding, and as in turn some if not all of the mineralization was genetically related to the intrusions, the tectonic history of the region is not without economic interest.

The bedrock of most of the gold-bearing areas of Seward Peninsula, especially in its southern part, consists of feldspathic and mica schists locally interbedded with metamorphic limestones that in places broaden out into considerable belts. The schist areas are also in places broken by wide belts of both massive and schistose greenstones and also by narrower belts of slates and quartzites. These formations are without doubt Paleozoic, and there is much evidence that they are younger than Silurian. They may be tentatively assigned to the Devonian or Carboniferous. The multiplicity of formation names in the many reports dealing with the geology of Seward Peninsula has caused much confusion in the minds of those not personally familiar with the region, hence it seems desirable to present at least a provisional correlation of the many formations that have been described, beginning with what are believed to be the oldest rocks of the peninsula.

Pre-Ordovician.—Dark slates and phyllites, locally graphitic, with some thin beds of limestone. These rocks have been definitely recognized only in the western part of the peninsula.

Ordovician with some Silurian.—Massive arenaceous limestone, locally crystalline. Typically developed in the western part of the peninsula, where these rocks are termed Port Clarence limestone. They carry Ordovician and Silurian fossils and, as mapped, some of Pennsylvanian age. Paleozoic limestone, with which are associated some dolomite and slate, is widely distributed in Seward Peninsula. For many of these rocks no definite age assignment is possible on the basis of the facts now in hand. The limestone beds at some localities carry Silurian fossils (in dolomite), some include Middle Devonian fossils, some are undoubtedly of Pennsylvanian age, and some possibly Ordovician.

Devonian (?).—Feldspathic, micaceous, siliceous, chloritic, and graphitic schists, with some beds of limestone, are very widely distributed over the region. The age of most of them seems to be pretty definitely later than Silurian, and there is some evidence that they are immediately succeeded by Pennsylvanian limestone. These rocks are provisionally assigned to the Devonian. In this group are included the Nome, Solomon, Kuzitrin, and Tigaraha schists and the schist of the Kigluaik group. It appears that the lower part of this series (Kuzitrin, Kigluaik, Tigaraha) is siliceous and the upper part calcareous. Most of the gold deposits of the peninsula have been found in association with the more calcareous members of this group of formations.

Carboniferous limestone.—Massive light-blue and white crystalline limestone. At Cape Mountain (Bering Strait) Pennsylvanian fossils have been found in this formation. The Sowik limestone of the Solomon region and the limestones overlying the Nome group are believed to belong to this formation.

Carboniferous.—Succeeding the supposed Pennsylvanian limestone in the Solomon and Casadepaga region are formations made up of black quartzose slates and schists not definitely recognized elsewhere in the peninsula. These have been termed the Hurrah slate and Puckmummie schist.

Carboniferous (?).—Greenstones are widely distributed in the peninsula, especially in the southern part. They occur chiefly as stocks, dikes, and sills, most of which have been rendered schistose. Their age is not definitely known, but they appear to be the youngest Paleozoic rocks of the region. The Casadepaga schist (chloritic) has been correlated with these rocks.

Intrusives.—Granitic and allied intrusive rocks occur as stocks and dikes in certain parts of the peninsula. They intrude the youngest of the known Paleozoic rocks and are for the most part Mesozoic or younger. Some of these rocks are sheared and gneissoid, as in the Kigluaik Mountains; others are massive, as those of the York district, where the granitic intrusives are accompanied by porphyry dikes. In the York district the mineralization is genetically related to the intrusives, and this is probably also true in some other districts.

There is good reason to believe that there was more than one period of intrusion. In the region east of Norton Bay mineralized rock accompanies granitic intrusives which traverse Upper Cretaceous beds and are probably of Eocene age. The opinion is ventured that the massive intrusives of the York district and possibly of some other parts of the peninsula are of Eocene age and were injected at the time of the latest period of deformation, which produced north-south folds. If this is true the other intrusives can logically be correlated with the older Jurassic (?) folding. So far as is now determined, this earlier period of intrusion was not accompanied by any very definite epoch of mineralization—at least, no evidence of mineralization has been found in association with the granites of the Kigluaik Mountains, which are believed to belong to the earlier epoch of intrusion.

Quaternary.—The Quaternary deposits consist principally of sand and gravel, with locally some small glacial moraines. During the Quaternary period there were poured out some extensive lava flows, which in certain places (Fairhaven and Kougarok districts) cover gravel deposits. In the Quaternary system also fall the terrace and ancient sea beach deposits that are especially well developed in the Nome and Solomon regions. Some of the lavas of the eastern part of the peninsula are probably pre-Quaternary.

COUNTRY ROCK.

The rocks of the area visited are nearly all metamorphosed sediments. Granitic intrusives are plentiful in the Kigluaik and Bendeleben mountains, north and northeast of Nome, but except for the granite of Cape Nome and of several smaller areas in the vicinity of Stewart River and Dickens Creek they are not known to be exposed in the area under consideration. Greenstone sills, stocks, and dikes are numerous but do not appear to have produced any mineralization. In fact, areas in which greenstones are abundant appear to be unfavorable to the occurrence of gold.

The metamorphic series consists mainly of schist but includes considerable limestone and some black slate. Chlorite schist is by far the most common type. It is usually siliceous, but calcitic varieties are common. Chlorite may be present almost to the exclusion of mica or may be only accessory to mica. The chlorite varieties are green; the micaceous varieties gray. The mica schists consist chiefly of muscovite and are highly siliceous. Feldspar schists are common in some parts of the area. The feldspar (albite) occurs in small crystals, together with chlorite and quartz, and the rock is not always easily distinguished from the chloritic types. Graphitic schists are present but are abundant only in small areas. The rocks are made up chiefly of quartz, massive and brittle, through which graphite is finely disseminated and with it a little muscovite. The schists taken as a whole are chloritic and siliceous. Graphitic, feldspathic, calcareous, and micaceous varieties are common but are subordinate to the general type. Accessory minerals, including biotite, are present in much of the rock, but these are nowhere conspicuous. The above-described schists belong principally to what has been called the Nome group.

Black slate is best developed in the Solomon region (Hurrah slate). It is a very siliceous rock, black, brittle, with good cleavage, and composed chiefly of quartz, with graphite, and here and there a little sericite. Lithologically similar types occur in the Council, Iron Creek, and Nome regions, but the fine slaty qualities are best developed in the Solomon region.

Limestone is an important constituent of the series. It occurs in thin beds generally not more than 50 feet thick and commonly only 5 feet thick throughout the schist series. It may occur as an occasional layer of limestone interbedded with schist, or it may form half of the section. As heavy-bedded limestone including thin beds of schist, it is most conspicuous and covers a considerable area. The beds are light gray or blue-gray to dark blue, are everywhere marmarized, and are in many places schistose.

STRUCTURE.

The structure of the rocks of the area is complex. Faulting has occurred in all the formations. Close folding is not unusual in the limestones and is common in the schists. The details of the structure are not well known. Two periods of deformation are recognizable. The axis of one set of folds strikes in general north; that of the other set east. The easterly folds are best developed in the vicinity of Kigluaik and Bendeleben mountains, where they are the prevailing structural features. Although they can be recognized throughout the area, they are elsewhere subordinate to the northerly folds. The areas of most intense deformation are the Nome and Solomon regions. Smith[4] has described in detail the structure of the Solomon and Casadepaga quadrangles, which may be considered as best illustrating the complicated geology that is rather characteristic of the peninsula as a whole.

[4] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 433, pp. 111-120, 1910.

MINERALIZATION.

ROCK OPENINGS.

The distribution and occurrence of the mineral deposits of a region are largely dependent upon the openings that were available at the time the mineral-bearing solutions were introduced. The extreme irregularity of many of the lodes of Seward Peninsula and the disseminated character of the mineralization are perhaps best explained by considering the stratigraphy of the metamorphic series, the contrast between the physical properties of the rocks of that series, the order of their succession, and the way in which they behaved when subjected to deforming forces.

Viewed in a general way the metamorphic series, principally mapped as the Nome group, is composed essentially of schist and limestone. at is not possible to give a measured section showing the relative proportions of the two rock types and their relation to each other, as the structure is complicated by intense folding and a great deal of faulting. Horizons are not distinguishable by lithologic data, and the limestones are fossiliferous in but few localities. Metamorphosed and unmetamorphosed greenstones add further complications, so that it is impracticable to subdivide the series other than into two parts, one predominantly schist, the other predominantly limestone.

The lower part consists chiefly of schist with interbedded limestone. The limestone beds range in thickness from less than 1 foot to perhaps 100 feet. Beds 5 to 20 feet thick are the most common. Few limestone beds of 20 feet or more do not contain one or several thin zones of schist. Not uncommonly the limestone and schist are about equally abundant and of about the same thickness. The most pronounced limestone zones include 20 to 30 per cent of schist interbedded with the limestone, and the most pronounced schist zones contain thin beds of limestone. Almost any ratio of limestone to schist or of schist to limestone can be seen in different parts of the area. The limestone is usually coarsely crystalline and fairly massive. Thin-bedded platy types and schistose phases also occur. The various types of schist that occur in the group have been described. They range from soft calcareous and highly chloritic varieties to dense brittle siliceous varieties. Slates are conspicuous in some parts of the area, especially in the Solomon and Iron Creek districts.

The limestone division of the Nome group, though chiefly limestone, includes many thin beds of schist ranging from 1 foot to 50 feet or more in thickness. The limestone is recrystallized and on the whole fairly massive, but zones of thin-bedded platy and schistose types are common. The contact between the two divisions is not sharp. In the limestone division schist is relatively most abundant at the base, and in the schist division limestone is relatively most abundant at the top.

The succession of limestone and schist is an extremely heterogeneous group. All degrees of so-called competency are represented not only among individual members of the group but among beds at various horizons throughout the group as a whole. The competent beds are the limestones, slates, and quartzose schists, and their competency within any zone is dependent upon their proportion and disposition relative to the less competent micaceous, chloritic, and calcareous members of the group.

A part of the gold mineralization is known to have occurred before the deformation of the series that produced most of the schist. Probably the larger part of the gold and apparently all the other valuable minerals were introduced later than the period of greatest metamorphism. The openings into which these later minerals were introduced resulted from folding or faulting of the heterogeneous series just described. All the later movements were not of the same age nor of the same intensity. Neither was all the later mineralization of the same age, but all the later openings were developed under similar conditions in a series of rocks whose physical characteristics were probably not much different at the different stages of deformation. The same principle, therefore, probably governed the formation of the rock openings in all the later periods of deformation.

As pointed out by Brooks [5] the most widespread effect of folding was to cause an adjustment within the series which to a large extent took the form of shearing at the contact of the so-called competent and incompetent beds. The physical properties of the rocks, other than their competency or resistance to deformation, were also important, especially those of the limestone. The uniform bedding planes of the limestone acted as original well-defined surfaces of weakness, so that when shearing forces were applied movement took place along these surfaces. These contact and bedding shear zones resulted in many poorly defined fissures which were distributed throughout the schist-limestone and limestone-schist divisions. Though the fissures were commonly not of great width and few of them are occupied by well-defined, massive veins, they permitted the infiltration of gold-bearing quartz and sulphide solutions and contain the quartz stringers so generally distributed through the area.

The controlling influence during deformation has been in large part the limestone and other competent members of the series, but exceptions to the localization of the fissures along the limestone contacts are so numerous that they require further explanation. Where the limestone beds are thick, as compared with the schists, the openings

[5] Brooks, A. H., U. S. Geol. Survey Bull. 328, p. 122, 1908.

seem to be closely confined to the immediate contact. Where the width of the schist zones is greater, adjustment within the relatively plastic schist beds has been effected by close folding, which has given rise to shears within the schist body and a general shattering of it. As the width of tbe schist zones increases, the fissuring becomes less closely confined to the contacts and more independent of the limestone. The most pronounced shear zones occur in bodies of schist several hundred feet in thickness in which competent beds are reduced to a minimum, but even here the action of the competent beds as the controlling factor during adjustment is recognizable. An especially favorable horizon for fissures formed by such shearing is at or near the junction of the main limestone division of the group and the underlying schist division.

Other fissures that cut the schist and the limestone are either not related to fissures that were produced by shearing or represent the extreme product of the deformation. A certain amount of deformation could be accommodated by the adjustment of the beds of such series as have been described, but if the deforming forces continued to act the beds would break. Fissures thus produced are the cleanest cut and most continuous observed and are occupied by the largest veins known in the area. Of the fissures in the schist even the cleanest cut show extreme irregularity. The physical properties of the schist did not permit it to fracture along sharp, well-defined planes. The fissures follow sinuous courses along both the strike and the dip, and horizontal movement along these sinuous lines has given to the veins which now occupy the fissures their habits of pinch and swell.

Only a few veins of considerable size fill fissures in the limestone division. The physical properties of the limestone cause it to break more evenly than the schist, and the veins in limestone are more uniform than those in schist. Any irregularities seem to be due to the division of the beds into blocks by joint planes and to unequal movement of the individual blocks, which resulted in straight-line reentrants and cavernous openings in the fissure walls. The joint systems and bedding planes in the limestone are the openings most commonly filled by later solutions.

The black slate member of the series is best developed in the Solomon region. It covers a very small area but is exceptional among the rocks of the series in the way in which it has fissured. It is a dense siliceous, uniform-textured rock which has fractured along clean-cut lines. The veins of Big Hurrah Creek occur in this formation and are the best defined and most regular of the veins known in the region. The contrast between the fracturing qualities of this division of the Nome group and those of the schist affords a good explanation why most of the veins of Seward Peninsula have proved so irregular and discouraging to prospectors.

TYPES OF DEPOSITS.

In this region concentrations of mineralization, especially of gold mineralization, are only relative. Dissemination is the rule. The concentrated deposits may be classed as veins and shear zones.

Veins.—Although the veins of Seward Peninsula have not shown great promise and have proved a source of discouragement to prospectors, because of their lack of continuity and the erratic distribution of the minerals which they contain, they are important in a study of the general mineralization of the region. They are known to be one of the sources if not the chief source of the placer gold. In addition to the original gold content of the veins, gold-bearing sulphides of a later period of mineralization have in many places followed the same fissures as the veins and fill fractures in the vein quartz and impregnate the schist of the vein walls. So far as known the original sulphide content of the veins was small.

Smith [6] has classified the veins as older quartz veins, newer quartz veins, and calcite veins. The calcite veins are abundant in both schist and limestone but especially in the limestone. Usually they occur as thin stringers and have attracted little attention as carriers of valuable mineral, but on Snow Gulch and Dry Creek, north of Nome, a number of tunnels have been driven on calcite veins that contain a little gold. The importance of the veins of this type is probably negligible.

The older quartz veins are those that antedated the period of extreme deformation and metamorphism in which the schists of the region were formed. Throughout the schist occur lenses and masses of quartz, some of which suggest by their outline that they are derived from or are deformed remnants of veins that were contained in the sediments at the time of their metamorphism. Smith [7] has noted that some of this quartz has had a different origin, being the result of the decomposition of silicate minerals during metamorphism. The quartz of the older veins is completely recrystallized, and nothing concerning the earlier history of their mineralization can be determined. Some of these veins are known to carry gold, but their very irregular occurrence eliminates them as prospective lodes.

The older veins are usually inconspicuous, and it is the later veins which are usually observed and to which prospecting has been largely confined. The later veins are not all of one period, but subdivision according to age is not possible. At the Big Hurrah mine, where veins of this type are well developed, smaller veinlets of several ages can be recognized, and veinlets of later quartz cut the quartz of the main veins. A further indication of the repeated or continued injection of quartz is seen in the ribbon rock at this locality. The

[6] Smith, P. S., op. cit. (Bull. 433), p. 90.
[7] Idem.

veins can be subdivided on the basis of accessory gangue constituents into quartz, quartz-feldspar, and quartz-calcite veins. They cut all the rocks of the series; they may be parallel to the bedding and schistosity or may cut them. They range in size from stringers less than an inch to veins several feet in width, but most of them are less than 6 inches wide. They are generally not traceable for more than a few hundred feet along the strike, and whatever their width, they are characterized by repeated and abrupt pinch and swell and irregularity of strike and dip.

The quartz of the veins is commonly white, clear, and vitreous and is stained by iron oxide on the fractured surfaces. Comb structure that shows several periods of vein growth is not unusual. The veins are characteristically of open texture, and the openings are usually cavities into which clear quartz crystals that show excellent terminations project. Some veinlets that cut schist are less than a quarter of an inch wide and show the open texture distinctly.

Where calcite occurs as an accessory constituent of the vein, it is commonly concentrated in areas through the quartz. Locally both quartz and calcite are present in about equal amounts, but usually the calcite crystallizes by itself in well-formed rhombohedrons. It may be white or stained yellow by iron oxide. Where tested it was nonmagnesian.

The feldspar type of vein is best known in the Nome area. A few of these veins occur in the Solomon area but are not conspicuous. The feldspar is everywhere of a plagioclase variety. Albite and oligoclase were about equally abundant in the thin sections examined. The feldspar occurs both disseminated through the quartz and segregated in small nests. It was nowhere seen to be present in any considerable quantity.

Sulphides of contemporaneous origin with the quartz occur in some of the veins. Pyrite is most common, but arsenopyrite and chalcopyrite have also been noted. Most of the sulphide is, however, safely assignable to a later period of mineralization, as it is usually seen to occur as veinlets in the quartz or in openings in the vein. Stibnite, arsenopyrite, and pyrite are the most abundant of the later sulphides. Galena, chalcopyrite, pyrrhotite, and bismuthinite are also known. Scheelite is a constituent of the veins in several localities, and from the general distribution of this mineral in the placers it is thought to be rather common and perhaps a minor constituent of the veins.

Shear zones.—Shear zones are exceedingly common, both in schist and in limestone. Most of the shearing, because of its very general distribution, did not cause concentration of the mineralization but rather the opposite. However, a type of shear zone is recognized in which there was considerable concentration and which may prove to be an important factor in determining the source of the placer gold. The zones of this type occur in schist, and many of them contain very little quartz; consequently they are soft and easily concealed by talus and moss. It can not be said how abundant they are, or what their distribution may be. They are very prominent in the Snake River drainage basin, and they are probably much more numerous than they appear to be, as their exposure is largely fortuitous. Stibnite, gold, and scheelite are present in these zones. The best-defined examples were noted at the head of Waterfall Creek, on the Christophosen property; near the head of Goldbottom Creek, in the California quartz lode; on Boulder Creek, in the Boulder lode; on Rock Creek, at Sophie Gulch; in a small gulch just west of Snow Gulch, tributary to Glacier Creek; in New Years Gulch, a tributary of Anvil Creek; and opposite the mouth of Specimen Gulch, on the northwest bank of Anvil Creek. Possibly certain hematitic schists that occur on Dexter and Dry creeks belong to this class of deposits, but they do not seem to be typical. (See fig. 18.)

These zones are characterized by disseminated sulphides. In some of them quartz is plentiful, but it is older than the sulphides. Comparatively little quartz seems to have accompanied the later mineralization. Where these zones are opened by mining operations fault planes are seen to cut the schist. The weathered outcrops are iron stained, and the soft, decomposed schist will pan gold and on assay shows a low gold content. The width of the zones is not well defined, for the mineralization gradually diminished with increasing distance from the faults. Where determinable, arsenopyrite is the most abundant sulphide impregnating the schist of these zones. Pyrite is also plentiful. Stibnite occurs at the Waterfall, Rock, and Anvil creek localities, but it is not known to be contemporaneous with the arsenopyrite. Scheelite has been mined from the zone on Sophie Gulch, but at this locality quartz veinlets are numerous and at least part of the scheelite occurs as a contemporaneous constituent of the veins.

As these zones carry gold, even if their content is too low to class them as commercial ore bodies, their importance as feeders for the rich placers of the district is evident. The width of many of them is measured in scores of feet, and in some localities they are said to have been traced for several thousand feet. As known, they represent rather good-sized bodies of low-grade ore, or rather mineralized rock.

Contact shearing and shearing within the limestone has resulted in concentrations of argentiferous galena and of copper sulphides.

At the contact of many of the massive limestone beds which occur throughout the schist division there is evidence of intense deformation. The limestone has been rendered schistose, and the schistose limestone grades into calcareous schist which in all probability has been derived from the limestone and represents the extreme phase of metamorphism. The limestone is in many places closely folded and contorted along the contact. Galena and sphalerite have been introduced along these horizons in several localities, and replacement ore bodies have been formed in the limestone and schist. The only deposit of this kind known within the area described occurs on Kruzgamepa River near the mouth of Iron Creek (p. 210). The ore here occurs as lenticular bodies in the schist and consists of galena and sphalerite in a gangue of quartz and calcite. On Kugruk River, near the mouth of Independence Creek, a deposit of lead-silver ore is being explored. The locality has not been visited by a member of the Geological Survey, but from descriptions it is understood to be a deposit of this type. At Omalik, in the Fish River basin, a similar deposit of lead-silver ore has been known for many years.[8]

At Iron Creek (p. 208) and Copper Mountain (p. 217) quartz carrying copper sulphides has been introduced along shear zones that have followed the bedding planes in the limestone, and the limestone has been replaced by silica. All the concentrations of copper minerals known in the area occur in deposits of this type.

Many of the relative concentrations in veins and mineralized shear zones grade imperceptibly into slightly mineralized country rock. Sulphides, chiefly pyrite, occur everywhere throughout the schist and slate of the Nome group and at many places in the limestone. Hardly a weathered specimen of schist can be found that is not specked with iron oxide, and thin sections show decomposed sulphide in every specimen examined. The schist as a whole is well mineralized. In the limestone the sulphides are less plentiful, but at its contact with schist and also adjacent to surfaces of movement within the limestone itself sulphides are almost always recognizable. Concentrations are frequently seen in the schist along the limestone-schist contact, occurring as tiny veinlets that cut the schist where it has suffered considerable distortion, coating fissures in the schist and coating the wall rock of quartz veinlets. It is not definitely known that the disseminated pyrite contains gold, but gold occurs chemically or mechanically combined with sulphides in some of the lodes of the area, and it is very probable that a part of the placer gold may have its origin in the disseminated sulphides.

Quartz veinlets from a fraction of an inch up to several inches in width occur in the schist in great numbers. They are nonpersistent, variable in width, and irregular in strike and dip. They appear to be almost nowhere concentrated to the point of forming a stringer lode. Such concentrations as occur are not sufficient

[8] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula: U. S. Geol. Survey Bull. 449, pp. 130–133, 1911.

to remove them from the class of disseminated deposits. The veinlets carry native gold. Stringers a quarter of an inch in width contain small nuggets. Free gold disseminated through the schists is not known to occur.

RELATION OF GOLD TO IGNEOUS ROCKS.

Brooks [9] has described the gold lodes of Seward Peninsula as deposits differing from the lodes of other parts of Alaska in that they show no genetic relation to intrusive rocks. Smith [10] cites the presence of tourmaline in many of the rocks as evidence that granitic intrusives which are not exposed may underlie the gold-producing areas and also correlates some of the later quartz veins with the intrusion of the granitic rocks of the Kigluaik Mountains. An examination of the geologic map, which shows a belt of granitic intrusives in the area of the Kigluaik Mountains, one prominent area of granitic rock at Cape Nome, and a few small isolated bosses as far south as Stewart River, suggests that the region between the mountains and the coast may be underlain by intrusive rocks.

Another criterion that may have some significance is the character of some of the later quartz veins, which are of the quartz-feldspar variety. In the Fortymile district Spurr [11] found similar veins and could trace the transition from granite to aplite to pegmatite to quartz-feldspar veins, and finally to quartz veins without feldspar. This evidence suggests that the veins of the Nome region especially have been derived from a granitic rock but represent a product a considerable distance removed from its source.

Another feature which suggests that the mineralization is related to a granitic rock is the widespread occurrence of scheelite in the placers. Scheelite occurs as a constituent of the quartz veins and is associated with the arsenopyrite. An analysis of the descriptions of 50 tungsten deposits, which include the most productive deposits of the world, indicate that some of their outstanding features are as follows: (*a*) The composition of the intrusive from which they are derived is usually that of a granite, although the deposits may be associated with rocks as basic as diorite; (*b*) the deposits may occur in the granite but usually occur in the country rock and have considerable ability to migrate from their source; (*c*) the traveling ability varies with the mineral. Scheelite is more likely to occur at a distance from the intrusive rock than any other tungsten mineral.

In the Kigluaik Mountains the granite is intruded almost entirely as sills and dikes. The few bodies of granite penetrating the Nome

[9] Brooks, A. H., Geologic features of Alaskan metalliferous lodes: U. S. Geol. Survey Bull. 480, p. 70, 1911.
[10] Smith, P. S., op. cit. (Bull. 433), pp. 132-133.
[11] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pp. 147, 291, 1896.

group south of the mountains are bosses, and the rocks are badly sheared. At one locality on Stewart River there is a granite which is so highly sheared as to be decidedly schistose, and its origin is not easily recognizable. It is possible that bosses and sills of granitic rock that have been converted to schist occur throughout the highly metamorphosed schists. Schists derived from igneous rocks have not been identified, however, and it is probable that if they are present the alteration has gone so far that they are beyond recognition.

It is not enough to say that the granite known elsewhere on the peninsula underlies the areas here discussed or that it may have been present and is now metamorphosed beyond recognition, for where the granite is known—in the York district and in the Kigluaik Mountains, for instance—it has not produced auriferous mineralization but deposits of tin, tungsten, and lead. It should be noted however, as suggested by Brooks (p. 168), that there may have been more than one period of granitic intrusion. Most of the gold deposits of Alaska are related to dioritic rocks. Diorite occurs at Cape Darby,[12] and andesite, quartz diorite, and monzonite occur in the Fairhaven district,[13] but elsewhere the intrusive rocks are chiefly biotite granites. If the quartz-feldspar veins are accepted as evidence of an underlying granitic mass from which the gold may have been derived, it is interesting to note that the feldspars of these veins wherever determined were plagioclase feldspars, albite or oligoclase. Plagioclase feldspar is an accessory constituent of the biotite granites, but it seems reasonable to assume that the character of the magma from which the veins are derived would be reflected in the veins themselves. The feldspars of the veins noted by Spurr [14] were orthoclase. It is not improbable, therefore, that the rock which is supposed to have produced the gold mineralization is a diorite such as has supplied the gold elsewhere in Alaska.

SEQUENCE OF MINERALIZATION.

It does not seem possible to assign a definite age to any of the several periods of mineralization which have been noted. The relative ages are known only in part. The two features of the age relations which are most impressive are (*a*) the number of periods of mineralization during which the various metals have been deposited and (*b*) the probable geologic youth of most of the sulphide, part of which is either gold bearing or was accompanied by gold and which seems to account best for certain of the well-known concentrations of gold.

[12] Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900: U. S. Geol. Survey Special Pub., p. 205, 1901.

[13] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 247, p. 30, 1905.

[14] Spurr, J. E., op. cit.

The order of succession may have been somewhat as follows:

1. The older quartz veins. These antedated the extreme metamorphism of the metamorphic series. How much of the disseminated sulphide and gold mineralization is assignable to this period is not clear. A large part of it is later.

2. Replacement deposits at limestone-schist contacts and along zones of bedding shear in limestone. The contact type includes the argentiferous galena of Iron Creek (p. 210); the shear-zone type includes the copper of Iron Creek and Copper Mountain (pp. 208, 217). The relative ages of these types are not determined. Galena occurs in small amounts as veinlets in the siliceous copper ores of Dickens Creek (p. 219) and as veinlets cutting the later quartz veins of Mountain Creek. If the galena mineralization is all of one age, the galena replacement deposits may be considerably younger than the copper replacement deposits.

3. The later quartz veins. The relative age of the copper replacement deposits and of the later quartz veins is also uncertain. That the former are merely a variation of the latter is questionable, however, as the copper sulphides are not prominent constituents of the quartz veins and the accessory feldspar and calcite of the veins are not known in the copper ores. In the Casadepaga district Smith found silicified limestone cut by later quartz veins. That the veins are of more than one period of intrusion is very probable, or at least their introduction was continued throughout some time, as shown by the vein structure at the Big Hurrah mine. From the evidence at hand, it might be best to consider the copper replacement deposits as older than the later quartz veins, although they may in part be contemporaneous. Geologically both of these types are fairly young. They are but slightly disturbed and certainly are subsequent to any of the periods of major deformation of the rocks of the peninsula. It is probable that they are younger than the late Cretaceous coal-bearing rocks, which occur in the eastern part of the peninsula, as those rocks are considerably faulted and folded.

4. Sulphide mineralization. Most of the sulphide minerals are probably younger than the later quartz veins. Practically all the stibnite and arsenopyrite and much pyrite are certainly younger. The pyrite is so abundant that it may have accompanied the mineralization of all periods. The age of the arsenopyrite and stibnite is shown by their association with the later veins. Movement sufficient to reopen the vein fissures and slightly shatter the veins supplied part of the openings into which these sulphides were injected. The movement that has occurred since the deposition of the stibnite is probably very slight, as those delicate ore bodies are not seriously disturbed. Slight movements are recorded in the several beach levels at Nome, the oldest of which may be Pliocene. The sulphide

mineralization would seem to be safely assignable to the Tertiary, but there is no evidence to indicate whether it was early or late in Tertiary time.

If the above interpretation is correct, it would seem that the sulphide mineralization and most of the gold mineralization of this area occurred subsequently to the mineralization which was effected by the granites in the York district. The York deposits are thought to be of Mesozoic age,[15] but that determination is also in doubt, as the granites do not occur in association with sedimentary rocks younger than Mississippian.

AREAS OF MINERALIZATION.

Most of the lode prospects of Seward Peninsula occur within two comparatively small areas—the York district, in the extreme northwestern part of the peninsula, and an area lying south of the Kigluaik and Bendeleben mountains, between Cripple River on the west and Council on the east. Prospects are also known near Kougarok Mountain, in the Kougarok Valley, on Kugruk River, at Omalik, and elsewhere, but most of the prospecting has been done within the two areas specified. It is very probable that these areas have been considered more favorable not so much because of the absence of lodes elsewhere which are as attractive as many or most of those that occur within the areas cited, but rather because of their proximity to tin placers in the York district and to the very productive gold placers of Nome, Solomon, and Council in the southern district. However, since the finding of gold at Nome, placer miners have pretty thoroughly covered the creeks of the entire peninsula and incidentally have investigated the promising lodes, so that, although the restriction of gold lodes may not be so great as is indicated by the distribution of the lode prospects, and other areas may possibly contain lodes of value, there was probably a relatively richer mineralization in the York and southern districts.

MINERAL DEPOSITS OTHER THAN GOLD.

In the foregoing description the bedrock occurrence of gold has been principally emphasized. There are, however, many other minerals on the peninsula of either proved or possible value. Some occurrences of these minerals are described in the following pages; others lie outside of the area under discussion.

Copper.—The copper ore of the area visited occurs in replacement deposits along sheared zones in limestones and schist and is characterized by features not observed in any of the other ores. At numerous localities the limestone, which is normally blue, is bleached

[15] Steidtmann, Edward, and Cathcart, S. H., Geology of the York tin deposits, Alaska: U. S. Geol. Survey Bull. — (in preparation).

to a lighter color or to white, and in places the bleaching is accompanied by silicification. These altered zones occur both at schist contacts and along planes of adjustment within the limestone and apparently unrelated to schist. The agency that effected the bleaching is not known. Silica has been introduced along the shear zones in places, and not uncommonly the bleached limestone is completely replaced. The copper sulphides that occur in these zones are contemporaneous with the quartz, but the quartz does not everywhere contain copper minerals.

This alteration of the limestone has been noted on Penny River, in the Solomon district, at Mount Dixon,[16] on Iron Creek, at Copper Mountain, on Slate Creek, on Manila Creek, and at Mount Distin. Copper minerals are associated with the altered limestone on Mount Dixon, Iron Creek, Manila Creek, and Copper Mountain, and zinc and lead at Mount Distin.

The quartz bodies in which the copper minerals occur seem to conform with the bedding of the limestone. The quartz contains many shrinkage cavities and retains the original bedding planes of the replaced rock. The most noticeable feature of the rock is its banded structure. Chalcopyrite, bornite, and pyrite are the usual sulphides observed. Galena is locally present. As all the developments are confined to the surface workings, malachite and azurite are the most abundant ore minerals.

Copper has been reported from the following localities:

Lost River, below the mouth of Tin Creek.[17]

Associated with the tin deposits of Ears Mountain.[17a]

About 3½ miles northwest of Kougarok Mountain, between Bismark, and Star creeks, tributaries of Quartz Creek.[18]

Three or four miles southeast of Kougarok Mountain.[18]

On Kougarok River near the mouth of Taylor Creek.[19]

Timber Creek and Tubutulic divide, Council City precinct.[20]

On the east coast of Darby Peninsula, about 3 miles north of Carson Creek.[20]

In the Bendeleben Mountains, on the divide between Kingsland and Nugget creeks.[20]

North side of Split Creek, a tributary of Bear Creek in the Fairhaven precinct.[21]

East of Iron Creek near the head of Sherette Creek, in the Kougarok precinct.

On Copper Mountain, Dickens Creek, and Copper Creek, at the head of Nome River.

On Dexter Creek, in the Nome district.[22]

On Mount Dixon, on Spruce Creek, and in the Moonlight Creek divide, in the Solomon district.[22]

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[16] Smith, P. S., op. cit. (Bull. 433), p. 115.

[17] Knopf, Adolph, Geology of the tin deposits of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 358, pp. 57–58, 1908.

[17a] Idem, p. 26.

[18] Mertie, J. B., jr., Lode and placer mining on Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 662, p. 440, 1917.

[19] Smith, P. S., Mineral deposits of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 345, p. 244, 1908.

[20] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 134–135, 1911.

[21] Harrington, G. L., Gold and platinum placers of Kiwalik-Koyuk region, Alaska: U. S. Geol. Survey Bull. 692, p. 399, 1917.

[22] Smith, P. S., op. cit. (Bull. 345), p. 243.

At the head of Twin Mountain Creek, in the Nome district.
At the head of Waterfall Creek.[23]
On the Klokerblok divide near the head of Eldorado Creek, in the Bluff region.
On the ridge at the head of Manila Creek.
Half a mile north of the mouth of Little Hurrah Creek, in the Solomon district.
Near the head of North Fork, a tributary of Last Chance Creek, in the Nome district.

At most of these localities copper is present in very small quantities, and at many of them development would hardly be justified. Little development work has been done at any locality.

Tungsten.—A small amount of tungsten has been recovered from the placers incidentally to the mining of gold. In the York district wolframite is associated with cassiterite in the tin deposits. It is present in very small quantities, so far as known, and has not contributed to the production. Scheelite is the mineral found in the placers and is present in small quantities at many localities. The concentrates from most of the streams of the Snake River valley contain scheelite. It occurs in the placers at Bluff, in the Council region, in the Solomon district, and in the Fairhaven district.

Sophie Gulch, a tributary of Rock Creek (p. 245), has been sluiced for its scheelite content. The gulch is cut in a shear zone in schist which contains a multitude of small quartz veins. The schist adjacent to the veins is impregnated with sulphides. Scheelite occurs with the sulphides that impregnate the schist and in the quartz veins that cut the schist. As the sulphide mineralization was later than the formation of the veins, and as scheelite appears to be contemporaneous with both the quartz and the sulphides, more than one period of tungsten mineralization seems certain.

Scheelite has also been mined from a quartz vein on Twin Mountain Creek and has been reported from lodes on the north side of Glacier Creek[24] and on the divide between Glacier and Anvil creeks.

Lead.—Within the area examined galena and sphalerite occur on Kruzgamepa River at the mouth of Iron Creek (p. 210) and on Steep Creek at the foot of Mount Distin (p. 232). At the former locality the ore is chiefly galena. It occurs as lenticular bodies along limestone-schist contacts. At Mount Distin the ore occurs in veinlets in a zone of bleached limestone. Galena is also present in very small quantities with the copper ores of Dickens Creek, Mountain Creek, Rock Creek, and Sophie Gulch.

Lead, in several places associated with zinc or with copper, has been reported from the following localities:

At Brooks Mountain.[25]
North of Rapid River, a tributary of Lost River.[25]
On Tin Creek, a tributary of Lost River.[25]
On Kruzgamepa River, at the mouth of Iron Creek (lead and zinc).

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[23] Mertie, J. B., jr., op. cit. (Bull. 662), p. 442.
[24] Idem, p. 437.
[25] Knopf, Adolph, op. cit. (Bull. 358), p. 42.

Northeast of Mount Bendeleben (lead and copper).
At Omalik.[26]
At the head of Steep Creek, on Mount Distin (lead and zinc).
On Kugruk River, at the forks of Independence Creek.
On Fish River, 5 or 6 miles above the mouth of the Niukluk.[27]
On Waterfall Creek.[27]

Most of the galena discovered on the peninsula has been reported to be silver-bearing. The property on Kugruk River has been actively exploited for several years and is the best-developed silver-lead prospect on the peninsula. A considerable tonnage of high-grade ore is reported to have been mined, but no shipments have been made. This property has not been visited by a member of the Survey.

Zinc.—The presence of sphalerite with galena at Mount Distin and on Kruzgamepa River has been referred to in connection with the occurrence of lead. Mertie[28] reports zinc to be present on the ridge between Penny River and the head of Oregon Creek. The ore consists of sphalerite and a little pyrite in a gangue of quartz.

Iron.—Five groups of iron claims have been staked on Cripple River. The ore is mostly limonite (pp. 258–261). Too little development work has been done to determine the nature of the occurrence. Mertie [29] reports sulphides as present with the ore at the Mogul group of claims and suggests that the iron may be merely gossan material capping a sulphide vein. The Cub Bear group of claims was visited by the writer. No sulphides were observed at this locality. The iron ore occurs in a zone perhaps 50 or 100 feet wide and extending for several thousand feet along the crest of an anticlinal fold in limestone. A small quantity of the ore is botryoidal limonite, with which some oxide of manganese occurs. Most of the material is iron-stained limestone and represents no great concentration of the iron oxide. The observed structural relations strongly suggest that the ore has been deposited from aqueous solutions circulating along the fissured crest of the fold.

Platinum.—Platinum is recovered from the placers of Dime Creek incidentally to the mining of placer gold. The ratio of the platinum to the gold content of the gravels is thought to be about 1 ounce of platinum to $4,000 in gold. Attempts have been made to locate the bedrock source of the platinum, and prospectors have received favorable returns on some of the material which they have had assayed. Specimens of greenstone dike rock which were reported to contain a trace of platinum were submitted to the Geological Survey, but assays made on this material for the Survey by competent chemists

[26] Mendenhall, W. C., A reconnaissance of the Norton Bay region, Alaska: U. S. Geol. Survey Special Pub., pp. 213–214, 1901.
[27] Mertie, J. B., jr., op. cit. (Bull. 662), p. 446.
[28] Idem, p. 447.
[29] Idem, p. 444.

have shown the rock to contain no platinum. Sulphides reported to contain platinum have been referred to under "Bismuth." The fact that platinum has seldom been found in hard rock does not preclude the possibility of finding it, but it can not be too strongly emphasized that platinum is an exceedingly difficult element to determine analytically. A platinum content is frequently reported when the element is not present. Prospectors can not afford to accept determinations by any chemist except one who is especially qualified to handle that particular work.

Antimony.—The stibnite that occurs in the area examined is commonly associated with the later quartz veins. Kidneys of stibnite accompanied by very little quartz have been found along shear zones in schist at several localities, but the ore bodies have been small. The best-known localities are the Sliscovich mine, on Manila Creek and the Hed & Strand mine, on Lost Creek (pp. 226, 229).

In all the deposits observed the stibnite seems to have been introduced since the formation of the veins. Apparently after the intrusion of the quartz movement continued to take place along the vein fissures, and they were reopened and the veins shattered. At some localities the stibnite occurs as irregular bodies between the vein and its schist wall and as nests and stringers in the vein itself. In most localities it is present only as veinlets in the quartz.

The stibnite is usually accompanied by some pyrite and a variable amount of contemporaneous quartz. In the richest specimens the stibnite occurs as distinct acicular crystals, some of which are an inch or more long, and the quartz is present as well-formed but smaller crystals with good terminations. In the lower-grade ore the stibnite is finely crystalline, and quartz forms most of the rock. Gold is present with the stibnite at the Sliscovich mine and at several places on Anvil Creek.

The localities at which stibnite has been reported to occur are as follows:

Sliscovich mine, Manila Creek.
Hed & Strand mine, Lost Creek.
Cold Creek.
Divide between Manila and Hobson creeks.
Big Hurrah Creek
Head of Waterfall Creek.[30]
Boulder lode.[31]
Quartz Gulch, tributary to Anvil Creek.
Winsted tunnel, northwest bank of Anvil Creek above Specimen Gulch.
Olsen shaft, southeast bank of Anvil Creek below Specimen Gulch.
Northwest bank of Anvil Creek below Quartz Gulch.
Ridge between Anvil and Glacier creeks, southwest of Snow Gulch.

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[30] Mertie, J. B., jr., op. cit., p. 438.
[31] Idem, p. 440.

Lost River region.[32]
Head of Bonita Creek, a tributary of Osborn Creek.[33]
California quartz lode, on Goldbottom Creek.[33]
Quartz veins of the Solomon-Casadepaga region.[33]
West side of Brooks Mountain.[33]
Omalik mine.[33]

Tin.—Lode tin is known only in the York district. Deposits have been prospected at Ears Mountain, Lost River, Potato Mountain, and Cape Mountain. Cassiterite occurs in quartz veins, porphyry dikes, and contact-metamorphic deposits closely related to granite bosses. Development work has been in progress at the Lost River locality for the last three seasons, but no work has been done at the other localities in recent years. The production from the lodes has been negligible. Most of the tin mined has come from the placers of Buck and Grouse creeks. The placers of Cape Mountain have produced some tin and, together with those on the streams flowing north from Potato Mountain, promise production for the future. Tin has been recognized in the placers of Humboldt Creek, in the Fairhaven district, and Goldbottom Creek, in the Nome district.

Bismuth.—Bismuth has been found at only one locality on the peninsula, on Charley Creek, a tributary of Stewart River (p. 223), where a quartz vein contains some bismuthinite (bismuth sulphide). The sulphide content of the vein appears to be low, but as almost no work has been done on the property very little of the vein is exposed. This occurrence has been of especial interest because the sulphide was reported to carry 2 ounces of platinum to the ton. An assay made on some of the material for the Geological Survey did not show any trace of platinum.

Graphite.—Graphite-bearing schists occur in both the Nome group and the Kigluaik group. The graphite in the schist of the Nome group is in a very finely divided state and is of no economic interest. A belt of schist of the Kigluaik group in which the graphite occurs as flakes and in which concentrations of rather pure material occur locally extends from the head of Grand Central River northeastward to the vicinity of Graphite Bay, an arm of Imuruk Basin. Several shipments of selected material have been made from the Graphite Bay locality (p. 222).

Mercury.—Cinnabar is a constituent of the placer concentrates in the vicinity of Bluff, at Koyana Creek, and at Budd Creek, in the Port Clarence precinct, and has been reported from other localities. The source of the material at Bluff is said to have been discovered in one of the schist lodes of that locality, but no details of the occurrence are known.

[32] Knopf, Adolph, op. cit., p. 59.
[33] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, pp. 57-59, 1916.

Coal.—A little coal occurs in the Cretaceous sediments of the eastern part of the peninsula. It is lignite of fair quality and is generally considered to have about one-half the fuel value of average Pacific coast coal. It is being mined at present on Kugruk River and has been mined at Chicago Creek, both in the Candle district. Thus far, because of the low grade of the product, the high cost of transportation has limited its use to the vicinity of the mines. No great tonnage is known to be available. Coal has been found at the following localities:

Chicago Creek, tributary to Kugruk River.[34]
Kugruk River near Montana Creek.[34]
Koyuk River near mouth.[35]
Wilson Creek, a headwater tributary of Kiwalik River.[36]
Hunter Creek near the mouth of the Buckland.[36]

THE LODE DEPOSITS.

BLUFF REGION.

The Bluff region, which has produced about $1,500,000 worth of placer gold, includes a small area lying on the shores of Bering Sea about 50 miles east of Nome. Its salient geologic features are simple, though the details are complex, due to folding and faulting. Limestone is the dominating country rock and occurs in a roughly triangular area, whose base is on the coast and whose apex is inland. This limestone appears to be bounded on the inland side (fig. 6) by schist which here and there contains some thin limestone beds. Some bands of schist also occur within the limestone, and these are important to the miner because they are the loci of the strongest mineralization. These bands of schist may in part be altered igneous intrusives, but this is uncertain. The small valleys of the region have a gravel filling, which is nearly everywhere auriferous and which contains some workable gold placers. The gold placers of Daniels Creek and of the adjacent beach line have furnished much the larger part of the gold output of the region.

Placer gold was discovered at the mouth of Daniels Creek in 1889.[37] The beach gravels at this locality were also gold bearing and for a distance of 1,000 feet are said to have been "probably the richest deposit of this kind ever found in the world." [38] It is estimated that the pay streak must have averaged $150 to the cubic yard.[39] Gold

[34] Henshaw, F. F., Mining in the Fairhaven precinct: U. S. Geol. Survey Bull. 379, pp. 362–363, 1909; Mining in Seward Peninsula: U. S. Geol. Survey Bull. 442, pp. 368–369, 1910.

[35] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, p. 139, 1911.

[36] Harrington, G. L., Gold and platinum placers of Kiwalik-Koyuk regions, Alaska: U. S. Geol. Survey Bull. 692, p. 384, 1919.

[37] Brooks, A. H., Richardson, G. B., and Collier, A. J., Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900: U. S. Geol. Survey Special Pub., p. 104, 1901.

[38] Brooks, A. H., U. S. Geol. Survey Bull. 328, p. 288, 1908.

[39] Idem, p. 289.

has also been mined from the creeks both east and west of Daniels Creek, but lower Daniels Creek and the beach at its mouth have proved to be the attractive placers of the area.

Brooks [40] pointed out from his study of the placers in 1906 that "(1) the source of the gold is entirely local; (2) where richest * * * there appears to have been little sorting action by water; (3) the gold is so intimately associated with mica schist débris that most probably the schist had a close connection with its origin." He also described certain zones of mineralized schist exposed in the bluffs east of the mouth of Daniels Creek.

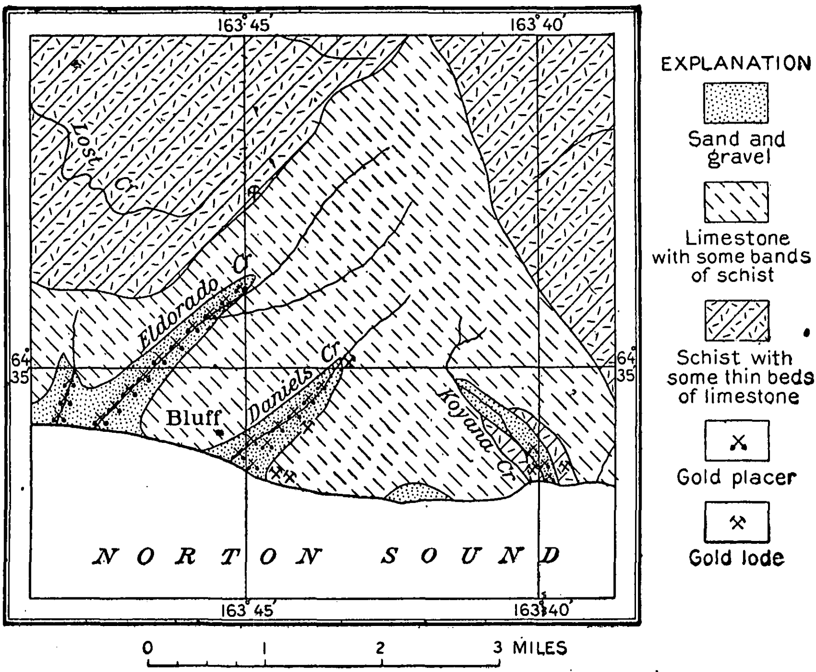

FIGURE 6.—Geologic sketch map of the vicinity of Bluff.

Several belts of mineralized mica schist have been recognized in the area, but those lying immediately east of Daniels Creek appear to be the most persistent and the most strongly mineralized. Before they are described brief mention will be made of some other occurrences of mineralized schist.

There is some evidence that Daniels Creek itself may be cut on one of these schist bands, though the nearest exposed bedrock on both sides is limestone. There is a schist band in the limestone at the mouth of Koyana Creek, and here mineralized zones have been opened up in a small way.

About 100 yards west of Koyana Creek near sea level an adit has been driven for 30 feet along a quartz vein in a sheared zone in the

[40] Brooks, A. H., U. S. Geol. Survey Bull. 328, p. 289, 1908.

schist. Owing to the timbering the relations and behavior of the vein can not be made out, but at the face an 8-inch stringer of quartz of the later-vein type (p. 173) is exposed. About a foot of red iron-stained gougelike material occurs on the vein wall. Sulphides occur in the quartz of the vein and in the schists near the vein but are largely localized along the contact of quartz and schist. Pyrite and arsenopyrite are abundant in the several places exposed, arsenopyrite the more plentifully. The zone of decomposition that forms so prominent a part of the lode is probably the result of the decomposition of the sulphides, especially of those contained in the schist. The tunnel was driven by David Lylles, but only assessment work has been done on the claim during the last six years. No information was obtained concerning the gold found.

About 50 yards east of Koyana Creek along the beach an adit reported to be 40 to 60 feet long is driven in a direction N. 50° E. A shaft sunk from the top of the escarpment to connect with the adit is said to be 75 feet deep. At the time of visit the shaft was filled with ice and water and a snowdrift covered the adit entrance, so that neither could be entered. This is known as the Hill property and is now claimed by Brady Hanson. Some ore was taken out, but very little has been shipped. The property was last worked in 1910. Material on the dump of the shaft is quartz-mica schist and quartz-vein material, apparently of the later-vein type.

A little work has been done on a metallized quartz vein on the Bunker Hill lode, on the divide between Eldorado Creek and Klokerblok River near the top of the ridge that parallels Eldorado Creek on the west (fig. 6). It appears to lie at or close to the contact between the limestones and schists.

The vein where exposed is about 5½ feet wide. Its relations to the country rock and its strike are poorly exposed by two shallow trenches about 2 feet deep and 20 feet long, of which one crosscuts the vein and the other follows its strike. The vein strikes about N. 5° E. and appears to dip west at an angle near the vertical. The footwall is limestone; the hanging wall schist. Where best exposed the vein shows a central portion of about 18 inches of unmineralized quartz with a foot of mineralized quartz on the footwall and 2½ feet on the hanging wall.

The vein is stained with carbonates, both azurite and malachite, and is said to carry gold. An assay of $80 in gold to the ton is reported by the owner, but nothing is known of the nature of the sample. The copper content is said to be small. A specimen of the metallized portion of the vein shows chalcopyrite and pyrite in small amounts.

As stated above, the deposits adjacent to and just east of Daniels Creek are the most valuable of the region. Here the mineralized schist bands in the limestone were staked as lode claims soon after the Daniels Creek placers were discovered. The original locators have carried on development work on these claims in a small way for some 20 years. Three lodes are recognized from Daniels Creek eastward, the Sea Gull, Idaho, and Eskimo lodes (fig. 7). They trend in a general northerly direction and except where they crop out on the cliff face are concealed by the tundra vegetation and exposed only by the mining operations. The Sea Gull and Idaho lodes lie parallel to each other; the Eskimo lode has the same attitude to a point 2,000 feet from the beach, where it swings slightly to the west, and at 4,000 feet from the beach the interval between the Eskimo and Idaho lodes is reduced by about one-half. Prospecting has shown the lodes to be continuous but of varying width, the width increasing to the north and in depth. Where explored at the croppings on the sea cliff maximum widths of 60, 165, and 150 feet are reported for the Sea Gull, Idaho, and Eskimo lodes, respectively. At 4,000 feet from the beach the widths are estimated from the workings to be 100, 200, and 200 feet, respectively.

The lodes are made up essentially of quartz-mica schist, silvery gray where fresh and buff where weathered. Quartz veins seem to occur everywhere throughout the schist and range in size from stringers less than 1 inch to well-defined veins several feet in width. Exposures are not adequate to afford conclusive evidence concerning the disposition of the quartz, but the veins appear to be somewhat concentrated along the margins of the lodes. The sulphides arsenopyrite and pyrite are recognizable in some of the lode material.

Four claims are staked along the strike of each of the three lodes, extending from the sea cliff nearly to the head of Daniels Creek valley. The most southerly claim on the Eskimo lode is held by John Corrigan; the remaining eleven claims by Charles Megan, Henry Megan, and W. J. Somerville. The schist zones have been traced by pits and shafts and are said to contain gold wherever prospected. Most of the work has been done about three-quarters of a mile from the beach, where fourteen shafts, ranging in depth from 30 to 100 feet and aggregating 657 feet were pointed out to the writer. They were distributed as follows: Sea Gull, five shafts, 240 feet; Idaho, six shafts, 335 feet; Eskimo, three shafts, 82 feet. Numerous pits and trenches have also been dug along the strike of the lodes, and on the Idaho lode at the beach 145 feet of tunnel, winze, and crosscut work has been done. The approximate location and depth of the workings are shown in figure 7. Mining has not been carried to any great depth, for several reasons. The shafts have been sunk chiefly for prospecting purposes, and it is said that no shaft failed to find gold-bearing quartz in sufficient quantities and rich enough to mine. The present mill equipment will handle, efficiently, only the oxidized surface portion of the

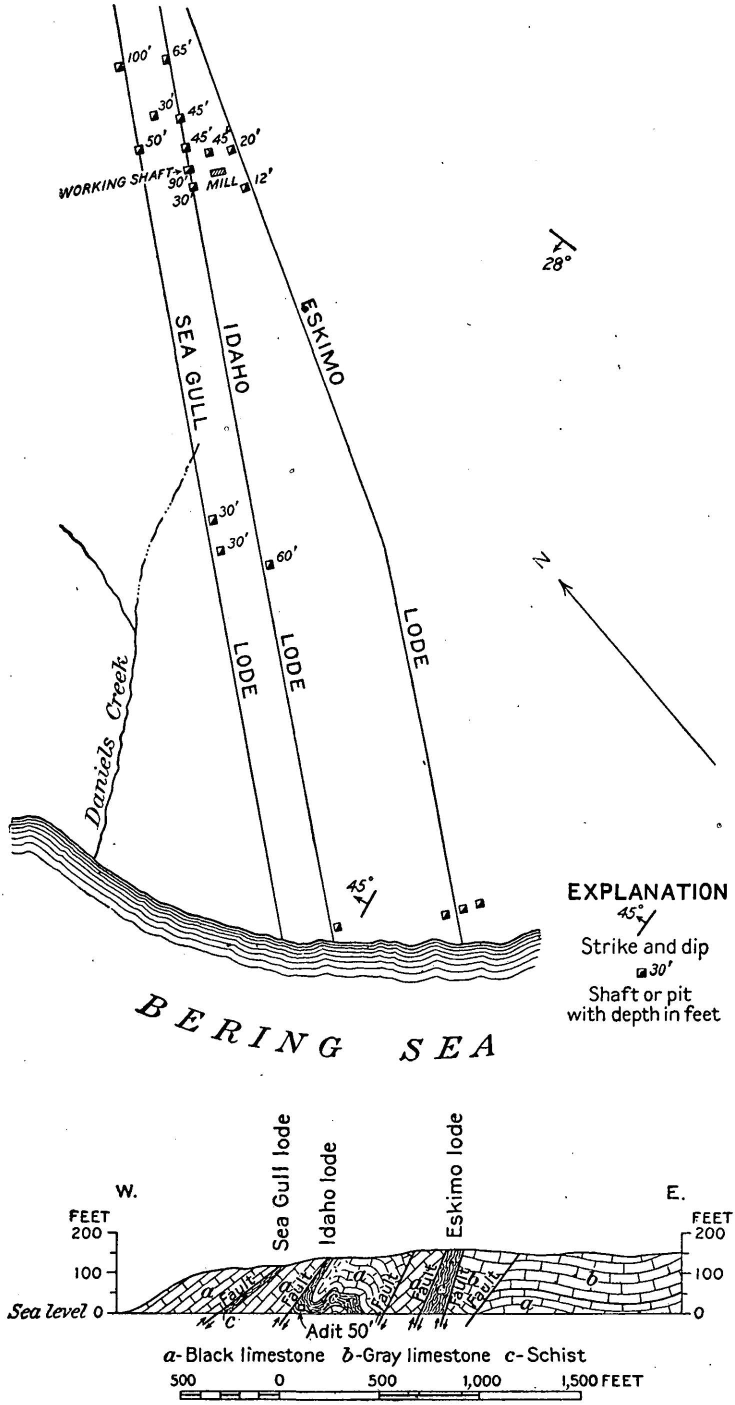

FIGURE 7.—Sketch map and geologic section showing gold lodes near Bluff.

lodes. There is no timber in the vicinity of Bluff, and mine supports are difficult to obtain. As the lode material is soft no considerable depth can be reached without danger from caving. Only the present working shaft is timbered; all the others are caved and inaccessible.

The rock formations with which the lode deposits are associated are exposed on the bluff that faces the sea just east of Daniels Creek (fig. 7). Three formations are recognized, a dark-blue carbonaceous limestone, a gray limestone interbedded with mica and chlorite schist, and the quartz-mica schist which forms the gold-bearing lodes. The lithology of the limestones is not uniform but shows variations which are dependent largely upon structural relations. The limestones are everywhere marmarized and show massive, slightly schistose, and highly schistose phases. The schist consists predominantly of quartz with some micaceous mineral. Muscovite is the common accessory constituent, with which usually occurs some chlorite, and locally the chlorite is in excess of the muscovite. The exposed schist is buff, and the less altered schist a silvery gray. The structural relations of the formations as exposed on the sea cliff are shown in figure 7.

East of the Eskimo lode the carbonaceous limestone is exposed at the base of the cliff. About 50 feet of the blue limestone is overlain by 100 feet or more of gray limestone. The contact is a fault plane concordant with the bedding of the limestones, which appear to be conformable. The rocks are gently folded into a syncline that pitches north. The blue limestone at the contact is dense, dark blue, and platy. The rock contains abundant graphite and considerable muscovite. Quartz is present in scattered grains that show the effects of strain. Cordierite is also present in small amounts. The overlying gray limestone is altered for a distance of several feetfrom the contact to a coarsely crystalline marble. The limestone lamination planes are marked by iron stain, which gives to the cross-fracture surfaces a blotched appearance.

The syncline is terminated on the west by a fault that brings the gray limestone down to form the footwall of the Eskimo lode. As indicated in the sketch map, this is the only occurrence of the gray limestone with the mineralized schists. The carbonaceous limestone adjacent to the schist lodes usually shows a schistose structure. This structure may be so well developed as to obscure its relation to the limestone, but where traced away from the lode the schistosity decreases until marmarized and slightly schistose but easily recognizable limestone occurs. The locus of deformation seems to be the Idaho lode, as here the folding and minor faulting and alteration of the limestone is most intense.

Only the major structural features are represented in figure 7. Many of the features are obscured by slide and made uncertain by the inaccessibility of the cliff face. Minor faulting and folding, or rather shattering and crumpling, is very common, especially in the vicinity of the lodes. Small faults occur in the blue limestone that do not extend into the gray, and vice versa. Many of these faults have a low angle of dip and swing off along the bedding planes. West of the Sea Gull lode the carbonaceous limestone is best exposed and least disturbed. It is fine textured and crystalline and occurs in beds half an inch to 8 inches in thickness, which strike N. 21° W. and dip 30° W. It is much jointed but broken in clean-cut blocks. The joints are filled with calcite veinlets, which average less than an inch in width and are spaced but a few inches apart. About 350 feet of the formation is exposed, the base in fault contact and the top eroded.

Some idea of the relations of the lodes to the country rock can be obtained at the exposure on the sea cliff. The underground exposures show little, as the development work in the one accessible shaft is confined to a single quartz vein and does not crosscut the schist body or show the relations of the schist to the wall rock.

The Eskimo lode, the most easterly of the three schist zones, is about 150 feet wide. It dips about 70° W. and occurs in fault contact with both footwall and hanging wall. The hanging wall is carbonaceous limestone; the footwall gray limestone. The sulphide mineralization of the schist was apparently concentrated along the footwall, where the limestone is stained buff and the schist weathers to a fine friable material and is highly iron stained. Microscopic examination of the rocks at the contact shows the schist to be probably 98 per cent quartz. It is strained, and the crystals are elongate parallel to the schistosity. A little muscovite is the only other original constituent present in any notable quantity, although accessory zircon occurs through the quartz. Calcite occurs in veinlets through the rock. The limestone is finely crystalline, is stained by limonite, and contains scattered cubes of pyrite.

Quartz veinlets are abundant in the schist, especially near the margin of the lode. No large or well-defined veins crop out. Fresh sulphides were not observed.

The Idaho lode is exposed on the cliff top about 650 feet west of the Eskimo lode. It differs from the other lodes chiefly in its structural relations with the limestone. The hanging wall is carbonaceous limestone, which dips 45° W. A fault dipping 35° W. forms the contact, along which 1 foot or more of gouge and talclike material occurs. The footwall is carbonaceous limestone, which near the base of the cliff occurs in folded relations with the schist of the lode. The infolding of the two formations is distinct, being outlined in minor as well as major folds. These relations are shown in figure 8.

The schist of the lode is highly folded and crenulated within itself. Quartz stringers occur through the schist in great numbers and appear to have been deformed with the schist, as they are badly shattered. The individual veins are mostly of small size and in general concordant with the schistosity of the lode rock. Along the hanging wall the veins are most abundant and reach several inches in width. The fault contact (fig. 8), which shows gouge and highly iron-stained schist, appears to be the best-mineralized part of the lode. The concentration of mineralization along the walls in this and the other lodes may in places be more apparent than real, being due largely to the fact that the contact surface afforded a better opportunity for water circulation and hence more complete decomposition of the sulphides contained in the schist. The gold content can be determined only by systematic assays. Assays of the Idaho lode are said to show gold throughout the width of the schist zone. The tenor is very irregular, however, ranging from $2 to $180 a ton.

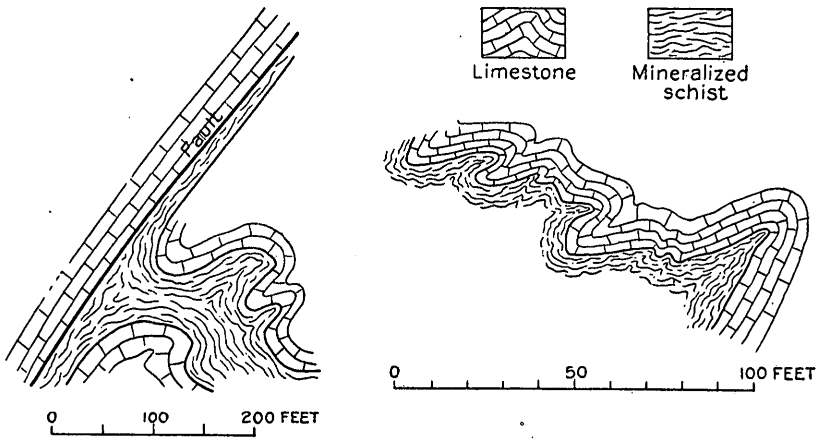

FIGURE 8.—Sketches of cliff exposure of Idaho lode, showing relation of mineralized schist to limestone

The highest values are shown by the material near the hanging wall, where the quartz veins and sulphides seem to be best developed.

The lode is 20 feet wide on the cliff top and about 50 feet wide at the beach, where, owing to folding, the exposure is about 165 feet wide.

The wall rock of the Idaho lode is a carbonaceous limestone consisting of about 90 per cent calcite, 5 per cent graphite, 4 per cent angular quartz, and 1 per cent sericite. Close to the lode it is distinctly schistose and marmarized and contains some pyrite. Metamorphism is more noticeable here than in the vicinity of either of the other lodes. Quartz is the dominating mineral of the lode schist, and with it occur chlorite and muscovite, chlorite the more abundantly. Accessory apatite and zircon occur through the quartz. Calcite and limonite are abundant secondary constituents. Polished surfaces of the vein quartz material show very minute particles of free gold. The sulphide content is not determinable at the cliff exposure, owing to the extreme alteration of the more highly mineralized portion of the exposed lode.

The Sea Gull lode crops out along the top of the sea cliff about 250 feet west of the Idaho lode. Exposures on the cliff face are obscured by talus. The lode is 10 feet wide at the surface and is said to be 60 feet wide at the beach, which is 110 feet lower in elevation. The increase in width is said not to be due to folding, like that in the Idaho lode. Both hanging wall and footwall are carbonaceous limestone, which dips about 30° and 45° W., respectively. The lode dips about 30° W. The hanging-wall contact is a fault surface, along which movement is recorded by gouge. The footwall contact is not exposed, but the relations are probably those of faulting. Along the hanging wall is exposed a zone of highly iron-stained schist, which is impregnated with quartz stringers from 1 to 3 inches wide. It is said that development work along this zone has exposed 6 to 8 feet of solid quartz at several places.

The limestone in which the lode occurs is crystalline and slightly schistose. The little-altered schist of the lode is a gray silvery rock, containing considerable sulphide both in the quartz and in the micaceous portion of the schist. On decomposition it becomes buff. Microscopic examination of a specimen from the hanging-wall contact shows the presence of abundant kyanite and of sillimanite in very fine crystals, together with the usual strained quartz, muscovite, chlorite, and decomposed sulphides. A polished surface of the quartz veinlet material shows free gold in very minute particles.

Work was being done at the time of visit on the Idaho lode about 4,000 feet from the beach. This was the only working accessible. A 90-foot shaft has been sunk on a quartz vein, and about 220 feet of drifts have been run along its strike. The vein is almost vertical. Where opened at the surface it was 8 inches wide, but on the 80-foot level it has a width of 7 feet. As exposed the vein shows three distinct types—an iron-stained shattered quartz, a green phase, and a softer hematitic phase. Where the three types are present, the quartz almost always forms the central part of the vein. The other types are less uniformly disposed. The hematitic material tends to localize along the walls, but in places it is confined to one wall. The green rock occurs between the hematite and the quartz or, if the hematite is absent, next to the wall. In several places it was observed extending into the quartz, and in one place it is surrounded by quartz.

The quartz of the vein is white and opaque and shows columnar crystals oriented transverse to the vein. Openings showing well-terminated crystals are common. The veins are of the later-vein type (p. 173). They are badly shattered, and in the fractures a green chloritic material commonly occurs. The green rock of the vein is composed chiefly of the chloritic material, in which occurs considerable of the vein quartz and fresh sulphides, chiefly arsenopyrite and some pyrite. In thin section the chloritic substance is pale yellow, is highly birefringent, and occurs as minute flakes in aggregate structure. In hand specimen the rock is deep green to yellowish green, hard, and usually cellular. The hematitic material is badly decomposed quartz schist. It is soft and crumbles in the hand. The unaltered wall rock is a silvery gray quartz-mica schist in which quartz is the chief constituent. The vein quartz is prominent even in small specimens of the schist. Viewed as a whole the wall rock is schistose; in detail it is essentially quartz. Next to the veins it breaks down readily and is of buff color.

The vein is continuous so far as followed but is not constant in width and shows still greater variation in make-up. In some places the quartz rock predominates, in others the green rock, and near the surface the red oxidized material of the vein. The red rock is favored by the operators, because of its high gold content and also because it is free milling. The buff schist is said to carry some gold but is not considered good pay. A certain amount of it is mined with the vein material and is milled as a part of the run of mine ore, which is said to have a value of $5 to $6 a ton. All the veins encountered in the prospect shafts are said to have been of this general type, varying in width and in proportion of the materials. The green rock occurs on the Sea Gull and probably on the Eskimo lode. Near the surface some of the veins are composed almost entirely of red oxidized material.

Prospecting has been confined to the oxidized zone of the lodes. The sulphide material was nowhere seen exposed, and its relations could not be determined. In specimens the relations are further obscured by the great amount of chloritic material associated with the sulphides. This chloritic substance is an infiltration product and is clearly later than the sulphide and quartz. The freshest of the quartz is cut by microscopic veinlets of this material, areas of unaltered arsenopyrite are surrounded by it, and shattered crystals are seamed with it. From the nature of the decomposed vein material and from similar occurrences elsewhere on Seward Peninsula, the sulphides are judged to be later than the quartz veins, having impregnated the schist of the vein walls and filled fractures in the quartz. The decomposed hematitic material, which is undoubtedly schist that has been impregnated by sulphides and weathered, mills free gold, but some gold is not recovered on the plates, and the gold content is probably in part base. Gold also occurs in the quartz of the open-structured veins, so that more than one period of gold mineralization may be represented.

In local usage the terms "hard ore" and "soft ore" are applied to the quartz-vein material and the schist country rock, respectively. Both the hard and soft ore are reported to carry gold, but the hard ore is said to be of higher grade than the soft. This relation does not necessarily mean that the schist and the quartz were mineralized individually, for the quartz solutions have so squeezed through the schist mass that the smallest openings have been filled, and many of the veinlets are so minute and occur in such an attitude that they would impart little of their hardness or resistance to the schist mass as a whole. The quartz may still remain the gold carrier, and thus the gold content of the soft ore or schist may be due to its contained metallized quartz veinlets. The larger veins have probably been considerably enriched by the later sulphide mineralization.

Four men were employed in mining at the time of the writer's visit. Dumps are taken out during the winter, and the ore is milled in the summer. It is crushed to 1-inch size in a small jaw crusher and reduced to 30-mesh in a Cover rod mill. The pulp is passed over amalgamation plates for gold recovery and then over two Monarch tables. The tables effect a concentration of 5 to 1 for the hard quartz ore and 20 to 1 for the soft schist ore. The concentrates are stacked. The mill has a rated capacity of 40 tons in 24 hours; the average run of quartz ore is 6 to 8 tons through 30-mesh in 24 hours.

The lodes have not been crosscut in any of the underground operations. The importance of crosscutting lodes of this type is very evident. From the evidence at hand it seems reasonable to believe that these zones contain one or more roughly parallel quartz veins, and although a single vein of low or moderate gold content may not prove to be an attractive mining venture, the presence of a number of veins which would in themselves offer a sufficient tonnage or which occur sufficiently close to one another to make mining of the entire schist and quartz body practicable might make the lode a commercial ore body.

Concentrates from Daniels Creek show scheelite and cinnabar, but neither of these minerals was observed to occur in the mill concentrates. The source of the scheelite is not definitely known, although it is probably present as a minor constituent of the quartz veins. Veins of this type carry scheelite in the Nome region. The cinnabar is said to have been found in place in the Eskimo lode associated with the schist. The working in which this was discovered is now caved, and the occurrence was not seen by the writer. Cinnabar is also said to be present in small amounts in the Idaho and Sea Gull lodes, and mercury is sometimes liberated on heating the mill pulp. It is also known in the placers of Eldorado and Swede creeks but has not been traced to its source. The fact that little placer ground has been discovered on Daniels Creek above the point where the lode system crosses its valley is further evidence that these lodes supplied the gold for the rich beach and creek placers.

SOLOMON DISTRICT.

Placer gold is widely distributed in the Solomon River basin, about 30 miles east of Nome, but little very rich placer ground has been found. Most of the successful alluvial mining has been done on the large bodies of auriferous gravel by means of dredges.

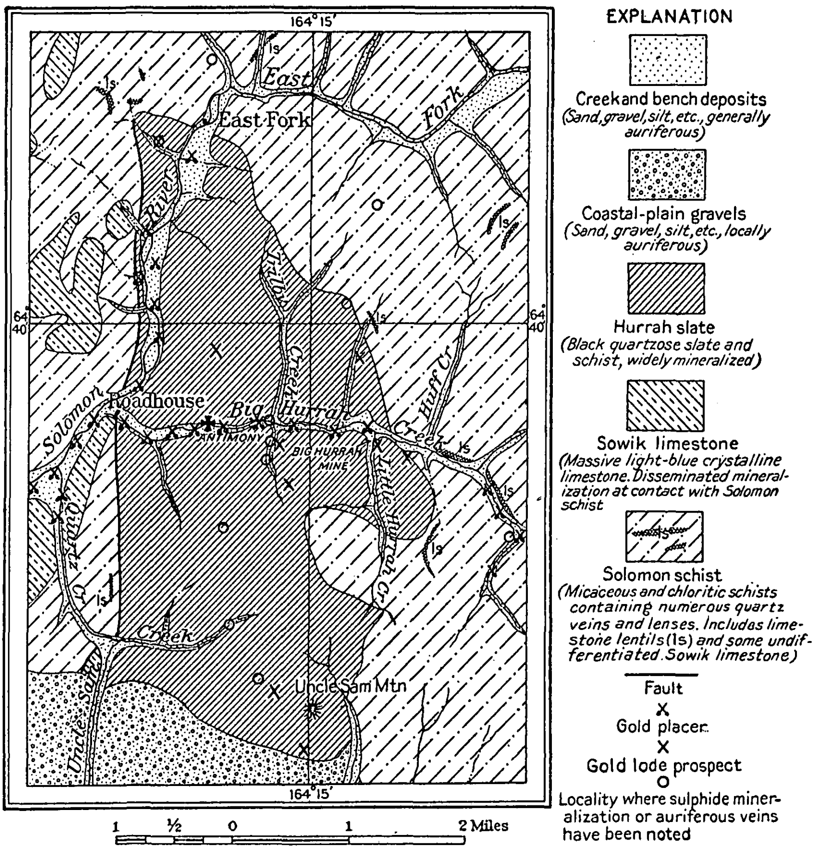

FIGURE 9.—Geologic map of part of Solomon district.

Smith [41] has mapped the region in detail, and part of his geologic map is here reproduced as figure 9. The Solomon schist, as determined by Smith, is the oldest formation. It consists essentially of micaceous and chloritic schists, with some lenses of limestone. This formation is succeeded by the Sowik limestone, 400 to 1,000 feet in thickness. Smith provisionally assigned the Sowik to the Ordovi-

[41] Smith, P. S., The geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 433, 1910.

cian(?), but Brooks now believes that it may be Carboniferous (p. 168). The Hurrah slate, a still higher formation, is made up of black and quartzose slates and schists.

Nearly all the most promising lode prospects of the region are in the Hurrah slate. There are, however, some quartz veins in the Solomon schist, and the contact between this schist and the overlying limestone is a common locus of disseminated mineralization. It is a significant fact that the gold of much of the richest placer ground of the district has been derived from the auriferous quartz veins of the Hurrah slate. The dominating trend of the lodes in this slate is northwest, but some northeasterly veins have been found. The veins are of the later-vein type (p. 173) and, with the exception of one antimony-bearing vein on Hurrah Creek, have been explored for their gold content. Sulphides are as a rule not conspicuous in the veins, and the gold is free-milling. The sulphides are mostly later than the veins and occur as veinlets in the quartz. Pyrite is the principal sulphide observed and the only one seen to occur as a contemporaneous constituent of the veins. Pyrrhotite and a little chalcopyrite are minor constituents of the sulphide veinlet at one locality on Hurrah Creek, and arsenopyrite occurs at the Alden prospects, on upper West Creek, in the schist area, and at the Flynn prospect, on Solomon River. On West Creek arsenopyrite impregnates the schist country rock in the same association in which it is so conspicuous in the Nome region. At the Flynn prospect it is present in a green chloritic rock very similar to the green rock of the Bluff lodes. The Big Hurrah quartz mine, which is the one productive gold lode of Seward Peninsula, is in this district. It is the only property in the district on which any considerable development work has been done.

As the occurrence of auriferous lodes in the Solomon district, cutting the Hurrah slate, may yet prove to be of commercial importance, some brief notes on several prospects and on the Big Hurrah mine will be presented, although the district, so far as lode mining is concerned, is now practically abandoned and the underground workings are for the most part inaccessible. A further difficulty is presented by the fact that not even the names of some of the prospects described could be learned. They have, however, all been marked on the map (fig. 9) by an appropriate symbol and can be identified by the descriptions of localities given in the text.

On the south side of Uncle Sam Mountain, near the level of the coastal plain, a shaft has been sunk on a quartz vein that cuts the Hurrah slate. The property has apparently not been worked for many years, and the relations of the vein could not be seen. The shaft is full of ice within 15 feet of the surface and is timbered to that depth. To judge from material on the dump the vein was probably 2 or 3 feet wide and from the drift has a strike of about N. 40° E.

The quartz is clearly of the later-vein type, showing comb structure and cavities lined with perfectly terminated crystals. No sulphides are seen in the quartz, and no fresh sulphides in the slate associated with the quartz contacts. Specks of limonite through the slate probably indicate decomposition of sulphides contained in it.

About 300 feet from the top on the south slope of Uncle Sam Mountain a massive iron-stained quartz ledge, 7 feet or more wide, has been exposed by an open cut. The vein strikes N. 45° W. and stands nearly vertical. The outcrop is iron stained, but no sulphides were observed. The transition from massive quartz to quartz with slate inclusions to slate with a little quartz is observed and probably indicates reopening of the vein. Decomposed feldspar is present in the vein quartz in small amounts. The wall rock is the Hurrah slate.

Iron-stained quartz that contains sulphides occurs as drift near the head of Buena Vista Creek, on the east slope of the valley, at an elevation of 500 feet. The ledge is not exposed. The country rock is the Hurrah slate. The quartz is of the later-vein type and shows many original cavities into which well-terminated quartz crystals project. Pyrite is abundant and apparently later than the vein. It fills cavities and coats quartz crystals.

Two openings have been made on quartz veins at the mouth of Buena Vista Creek, on the east bank. One is now caved and inaccessible; the other, a drift 15 feet long, follows an 8-inch quartz vein. The vein strikes N. 45° W. and dips 60° S. The wall rock, which is black slate, strikes N. 50° E. and dips 45° N. The vein is variable in attitude, here cutting the bedding of the slate, there following it. Just north of the drift face the vein is offset 5 feet by a fault that has followed the bedding of the slate. This is a minor dislocation such as is commonly observed to affect the later quartz veins. Ribbon rock was not seen here, the vein walls being clean cut and not affected by the mineralization. The quartz is iron stained on fracture planes and contains pyrite, which occurs both as crystals through the quartz and in cavities and fractures later than the quartz. Two ages of sulphide mineralization are here apparent.

Considerable prospecting has been done about half a mile from the mouth of an unnamed stream that enters Big Hurrah Creek from the north a quarter of a mile below Little Hurrah Creek. The workings are now so caved and slumped that no exposures of the veins can be seen. There are probably a dozen open cuts from 5 to 30 feet long and 3 or 4 feet deep and three shafts, now caved and filled with water. The country rock is the Hurrah slate.

Quartz on the dump at the main shaft is of open texture, coarsely crystalline, and clearly of the later-vein type. Considerable sulphide occurs through the quartz in well-defined veins, which in places swell to nests. Pyrite and pyrrhotite are the principal sulphides. Some arsenopyrite is present, and chalcopyrite is recognizable on a polished surface. The gold content of the vein is not known. So far as could be observed, the vein is structurally different from most of the other gold lodes of the district in the absence of ribbon rock, and it is mineralogically different from most of the other sulphide-bearing gold lodes in the absence of arsenopyrite and the presence of pyrrhotite and chalcopyrite.

A vein of quartz has been opened by a trench 10 feet long and 2½ feet deep on the south bank of Big Hurrah Creek about half a mile above the mouth of Little Hurrah Creek. The trench is now so filled with wash that the vein can not be seen. The dump shows mica schist of the Solomon schist and iron-stained quartz vein material, including lenses of schist. The opening is near the contact of the Solomon schist and Hurrah slate. The bedrock schist is a highly quartzose mica schist with probably some chlorite. The vein is made up of large, well-defined crystals, many of which show good terminations and comb structure. Several reopenings of the vein are recorded in one hand specimen. The schist at the contact appears to be silicified, and open texture along the contact is the rule.

The Big Hurrah lode was discovered in 1900, opened up in 1903, and then equipped with a mill and operated on a productive basis until 1908. Since then the property has been idle, and at the time of the writer's visit the underground workings were for the most part inaccessible. Smith's description[42] of this lode is the primary source of the following notes, but they also include some supplementary observations made on the surface exposures and open cuts near the mine. This deposit is one of the few auriferous lodes on Seward Peninsula whose continuity and structural relations are known by extensive underground openings.

The Big Hurrah quartz veins are about the only veins of any great size and proved continuity known on Seward Peninsula. They are several feet in width and are not subject to the pinch and swell and extreme irregularity that have been found to be characteristic of most of the veins on the peninsula. The reason for the difference in the habit of these veins lies in the character of the country rock—the Hurrah slate, a brittle rock that fractures readily and breaks along sharp, clean-cut lines. These physical properties of the slate are not found in the schist and limestone formations that form the bedrock of most of the peninsula, and even the limestones lend themselves less readily to this form of opening.

The three quartz veins that form the lode are roughly parallel in strike. Two of them dip to the southeast and the other to the northwest. They crop out on the bank of Little Hurrah Creek, have been followed by underground workings for several hundred feet to the

[42] Op. cit., pp. 143–147.

south, and are 4 to 8 feet wide. Considerable prospecting has been done west of Little Hurrah Creek and north of Big Hurrah Creek in the black slate area, in the hope of finding the continuation of the veins or others equally favorable to mine. Little success has attended such attempts, and to date the veins are known only within a very small area of slate between the forks of Big and Little Hurrah creeks.

The main developments at the Big Hurrah mine have been by means of an incline shaft, which has a general though not constant slope of about 60°. The strike of the veins is northwesterly, and the dip is to the southwest. The upper portion of the vein has also been worked in part by adits run in from the outcropping of the vein on Little Hurrah Creek. A general plan of the underground workings is shown in figure 10.

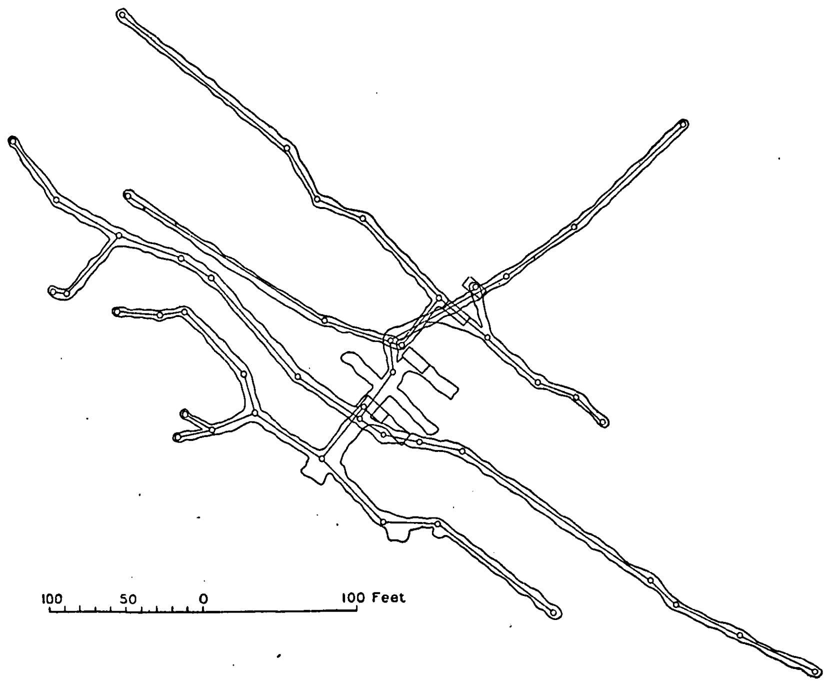

FIGURE 10.—Plan of underground workings of Big Hurrah mine.

North of the main lead there is another vein about 50 feet below in the footwall. This vein, unlike the two farther south, has a northwesterly dip, although the strike is essentially the same as the others.[43]

It was at one time a question with the operators of the property whether the opposite dipping lodes were two distinct veins or limbs of an anticlinal fold. There seems to be no evidence to support the latter theory, and the general attitude of the formation and its minor structural features seem to point to their being two distinct veins.

If the underground conditions at the mine could be studied or the discoveries made during the development work learned, considerable data would probably be available upon which to base a conjecture

[42] Smith, P. S., op. cit., p. 145.

concerning the probability of finding these or similar veins beyond their present known limits. As such data are not to be had, only surface observations can be made. Examination of the open-cut exposures is far from satisfactory but seems to justify certain generalizations. On the east side of Little Hurrah Creek the slate is badly fractured but not appreciably folded. The slate cleavage here strikes N. 10° W. and dips 45° S. Jointing here is the common structure; it is very pronounced and complex. Joints traverse the slate in all directions and with dips extremely variable in direction and amount. The following series was observed on one face:

Strike N. 75° W.,	dip 45° N.	Strike N. 75° W.,	dip 65° S.
N. 25° W.,	65° E.	N. 80° W.,	45° S.
N. 40° E.,	40° S.		

Dips in the slate have little significance, as they are very local and variable. Dislocation along the joints was probably accompanied by tilting of the blocks, so that exposures within a few feet show dips at variance.

On the west side of Little Hurrah Creek the general attitude of the slates is markedly different. Here folding rather than jointing is the characteristic structure, and both gentle open folds and close abrupt folds may be seen. Jointing is of course present, but it is not the predominant structure.

The most pronounced fold observed is exposed in a small drift along the creek bank. A quartz vein 8 inches wide conforms with the fold and is therefore later than the folding. The fold resembles a drag fold along a fault. The strike of the fold is north and the dip west. At another locality 30 feet downstream a second drift exposes a 4-inch quartz vein. The slate here too is folded, and the fold pitches west. The quartz vein is later than the folding and well illustrates the attitude and extreme irregularity of many of the veins that have not followed well-defined joint planes.

Some evidence was obtained at this locality to show that there was more than one period of intrusion of the later quartz veins, separated by a period of slight deformation. There is also evidence of two systems of folding—one comprising open folds whose axes strike east and the other comprising closed folds and faults that strike north. What is believed to be a fault belonging to the northerly system follows the course of Little Hurrah Creek. Differences were noted in the general type of predominating structure on the east and west sides of the creek and also the presence of what are probably drag folds along the creek bank on the west side. These features denote that the west is the downthrown side of the fault. The failure to find an extension of the lodes west of Little Hurrah Creek may be due to this supposed fault.

Concerning the probable extent of the veins to the southeast more conclusive evidence is to be had. As shown on the geologic map (fig. 9) the Hurrah slate forms the country rock for about 1 mile south of the mouth of Little Hurrah Creek and a quarter of a mile to the east, where it is in contact with the Solomon schist; such relations in themselves indicate fault contact. Pits dug along the strike of the veins to the southeast have exposed Solomon schist in the area mapped as black slate. On the basis of this evidence, the veins can not extend in black slate country rock for more than 800 feet, and to judge from outcrops in the creek bank the distance is probably less. The favorable character of these veins is so evidently due to the physical properties of the slate formation in which they occur that they can not be expected to continue into the Solomon schist and persist in their present form, for the schist is decidedly less hospitable to vein formation.

It is not known whether the faulting at the slate and schist contact was earlier or later than the intrusion of the quartz vein. If the veins are older than the faults, as the schist is the older formation and separated from the slate by several hundred feet of Sowik limestone, the schist indicates a relative upward displacement of 400 feet or more. In this case the slate with its contained veins has been removed by erosion, and its gold has gone to supply the local placers. If the intrusion of the veins was later than the faulting they probably never existed in the schist as the well-defined veins that have been mined in the slate area.

The ores of the Big Hurrah mine were free-milling and are said to have averaged less than $20 a ton in gold. Ore of two types was mined—quartz-vein material and ribbon rock—and the latter is reported to have yielded the better returns. Ribbon rock, as the term was here used, included rock showing alternate roughly parallel laminae of quartz and slate, also slate cut in all directions by many small contemporaneous veinlets of quartz, which in places formed more than 50 per cent of the mass. This banded rock was probably due to reopening of the vein and repeated injection of quartz. The other type probably represents shattered wall rock of the vein. The veinlets are as a rule clean cut but locally show curving and ramifying tendencies. The slate consists essentially of quartz with abundant graphite, considerable white mica, and limonite, which give to the rock a very fine lamination. The ribbon rock ranges from quartz with occasional fine laminae of slate to slate with a minor content of quartz.

The vein rock is coarsely crystalline vitreous white quartz of the later-vein type, showing cavities into which well-terminated crystals project. The small veinlets of the ribbon rock are of the same open-textured vein type. In some of the veinlets the quartz crystals project from one wall only; in others the fissures are incompletely filled by crystals projecting from both walls. A little white mica is the only other constituent of the veins observed microscopically, but decomposed feldspar was seen in some hand specimens and is probably a minor constituent of the vein. The quartz is strained and in places shattered. Fissures through the quartz filled with later quartz give further evidence of movement and more than one injection of quartz. Native gold can occasionally be seen in hand specimens. Microscopically it is seen to occur with the quartz of the vein. Sulphides are almost absent. Neither the sulphides of the vein nor the carbon of the schist were observed to be associated with the gold.

The Gray Eagle claim, an antimony prospect, is on the north bank of Big Hurrah Creek about 1 mile from Solomon River. A 12-foot shaft has been sunk and several trenches dug on a 4-foot quartz vein which carries stibnite. The country rock is the Hurrah slate. The workings are now caved, and the vein is not exposed. No work has been done here for five years. The claim is owned by E. W. Quiggley, who reports the vein to be 4 feet wide and to strike about N. 45° E. and dip 45° N. The stibnite is said to occur throughout the width of the vein. The center of the vein for a width of 1 foot is said to be almost pure stibnite, and the sulphide to occur in nests through the rest of the vein.

Specimens from the dump show the ore to be an intimate admixture of stibnite and quartz crystals occurring through the quartz of the vein. Columnar crystals of stibnite an inch in maximum size occur with clear, glassy, well-terminated crystals of quartz half an inch or less in width. The quartz of the vein, which is free from stibnite, is of the open-textured later-vein type. The material examined did not show definitely the relation of the sulphide to the vein, but it is probably later.

Near the top of the hill northeast of the mouth of Big Hurrah Creek considerable work has been done on the Flynn gold quartz vein. Here there is an inclined shaft, said to be 60 feet deep but now filled with water. Probably 20 smaller shafts and trenches, some of which are 50 feet long and 3 to 8 feet deep, show quartz on the dump, but no vein is exposed. The country rock is the Hurrah slate. In addition to quartz, a green mineralized rock occurs on the dump of a shallow shaft, now filled with water. The rock is composed of fresh arsenopyrite and a very little quartz in a mass of chloritic material such as forms the green rock of the Bluff lodes. Much of the quartz on the dump is of the ribbon-rock type. It is iron stained, but no sulphides were observed. The size, attitude, and relations of the vein could not be seen or learned, as no one is on the property and no work has been done for five years.

Two other prospects within the basin of Solomon River but outside of the area included in the map (fig. 9) will be briefly mentioned.[44]

On the first tributary to Solomon River from the west below East Fork an adit has been driven on a vein occurring in the black graphitic slates. This vein is located along a fault which has an indeterminate throw and is distinctly later than the fault. The amount of mineralization is not very great, although in places the rocks are considerably iron stained. The adit is only 20 feet long, and the mineralization becomes progressively less toward the breast, and the amount of drag indicated by the wall rocks also diminishes. No work has been done at this place for some time.

Several openings have been made on lodes on West Creek, which flows into Shovel Creek, a westerly tributary of Solomon River. These occurrences are described by Smith [45] as follows:

A series of veins occurring in the chloritic-schist areas away from any contacts with other rocks has been opened on West Creek 2 miles above the mouth. Some work is done here every year, and there are 600 or 700 feet of underground workings, but the mine has not yet shipped any ore. The development is on a north-south vein, which was opened by an adit that drifted along the vein for over 350 feet. In this drift both walls were decomposed chloritic schist, which in places showed marked slickensiding. Another adit about 300 feet long has been driven on a vein farther west, which shows the same general character as the first. A crosscut following a small cross stringer has been run from the eastern drift. The quartz from all the veins is practically the same in character. It is white and somewhat shattered but is apparently not sheared nor folded and presumably belongs to the later set of veins. In addition to the quartz the veins carry abundant chlorite and a small amount of pyrite and marcasite. The later metallic minerals occur in small stringers and vugs. The wall rocks are also said to be gold bearing, and the footwall schist is reported to carry from $8 to $10 a ton in gold, but no assays of the rock have been made by the Survey.

COUNCIL DISTRICT.

The Council district has been a large producer of placer gold for 20 years. No valuable metalliferous lodes have been developed in the district—in fact, very few lodes have been found. It appears that a large part of the placer gold is derived from mineralized zones in which the metal has not been sufficiently concentrated to form lodes of commercial value.

The rocks of the district include limestone and schist of various types with a little slate. These rocks strike northeast and almost invariably dip southeast at angles of 25° to 45°. A belt of massive limestone forming the ridge west of Ophir Creek is the only well-defined unit of the district. The bedrock of the rest of the area consists of schist and limestone in varying proportions. On the accompanying sketch map (fig. 11) these rocks have been differentiated into a series in which the schist and limestone occur in about equal proportion, and a series which is largely schist with only subordinate amounts of limestone. The sequence of these beds, if indeed they are distinct formations, has not been established.

[44] Smith, P. S., op. cit., p. 148.

[45] Idem.

The larger features of the geology are not complex, and the uniform southeasterly dip suggests a simple monocline. There are, however, many shear zones in which some of the limestone has been altered to calcareous schist, so that it is difficult if not impossible to trace beds and groups of beds for any considerable distance. It is not impossible that the apparent monocline may actually be an overturned fold, perhaps accompanied by thrust faults, though no

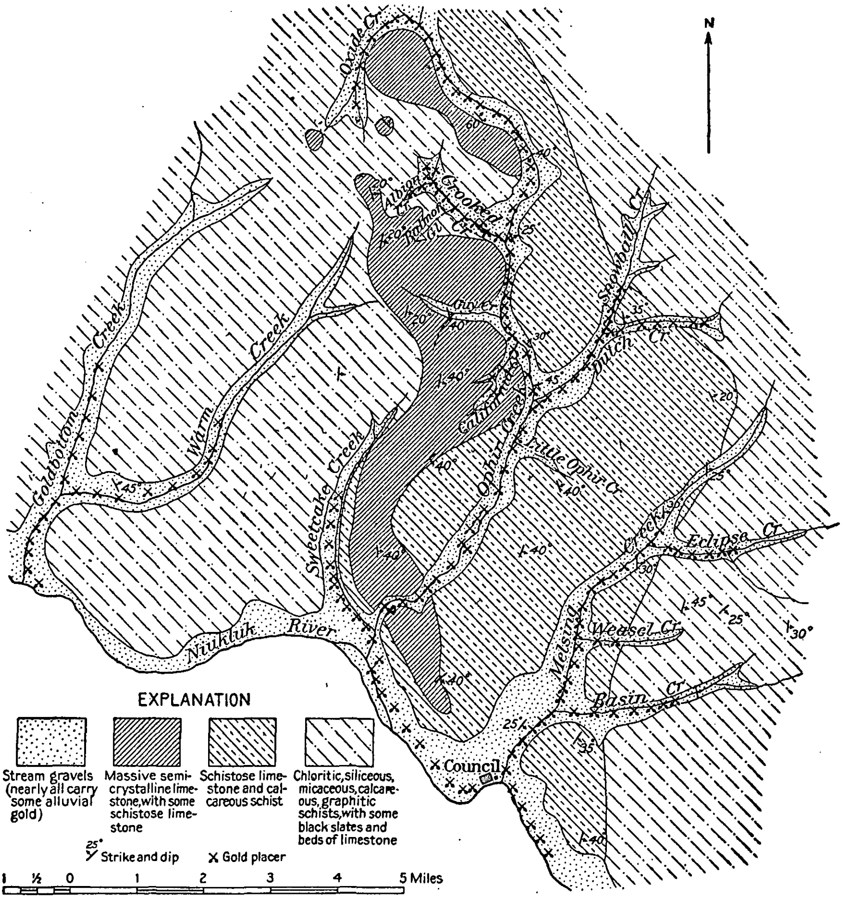

FIGURE 11.—Geologic sketch map of part of Council district.

evidence of faulting was found. The map also shows the approximate distribution of the stream gravels. Practically all these gravels carry a little gold, but it is only in certain localities that these auriferous gravels are rich enough to afford valuable placers.

Few lodes that have encouraged hard-rock prospecting have been discovered in the Council district. The mineralization of the country rock from which the very rich placers of Ophir Creek have been derived does not seem to have been sufficiently concentrated at any locality to form a lode, but rather the gold has been disseminated throughout the bedrock. Quartz stringers and sulphides are very common in the schist and limestone, especially in the schist. The quartz is known to carry gold, as some of the veinlets are reported to show a gold content on assay and quartz is frequently found attached to gold in the placers. That quartz is the only carrier of gold in the district has not been proved. Some gold may occur with the sulphides, but its presence has not been demonstrated. It is perhaps safe to assign most if not all of the gold to the quartz veinlets, as the sulphides are almost entirely pyrite, and the gold that occurs with sulphides elsewhere on the peninsula is associated with arsenopyrite or stibnite.

The nature of the occurrence which would permit the gold to be so generally distributed throughout the country rock and not tend to produce lodes has been discussed by Brooks,[46] who, from his study of the region, has shown the gold to be related to the limestone and schist contacts. The behavior of the limestone and schist series when subjected to intense folding has been discussed on page 171. The shearing incident to such folding is believed to have supplied openings along the contacts of members of the series which differed in resistance to shear, and these openings were later filled by quartz veinlets that carried the gold (fig. 12). The country rock of the Council district was especially favorable for this mode of occurrence, either because it comprised a series which was originally very heterogeneous and which consequently offered a great many such contacts or because schist zones had been developed within a massive limestone as the result of the shearing. There is evidence that many of the schist zones have been derived from the limestone, as the schist is mostly of the calcareous variety. All the limestone is somewhat schistose, and the transition from slightly schistose limestone through schistose limestone to calcareous schist is frequently seen. West of Sweetcake Creek and east of Melsing Creek the schist is largely siliceous and limestone is not a prominent member of the series. (See diagram, fig. 12.) Between Sweetcake Creek and Ophir Creek and extending north to Crooked Creek is an area which is occupied chiefly by limestone. Between Ophir Creek and Melsing Creek schist and limestone alternate. The schist is largely calcareous, and the limestone is rather schistose. The schist appears to increase and the limestone to decrease in amount toward the east. Ophir Creek, the most productive creek of the area, flows through that part of the series in which the contacts are most numerous and in which quartz veins are most plentiful. Guy Creek,

[46] Brooks, A. H., The gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, p. 123, 1907.

the least productive creek of the area, flows through the massive limestone member of the series and cuts only one schist zone. Crooked Creek and its tributaries are cut through the limestone member and into the underlying siliceous schist, which at its contact

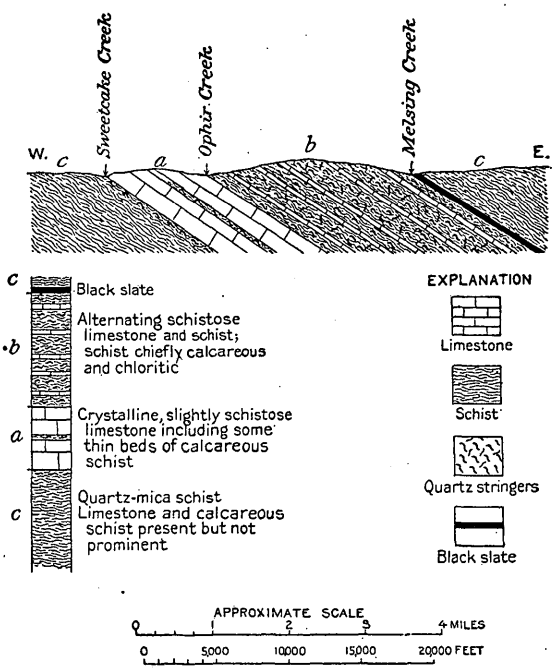

FIGURE 12.—Diagrammatic cross section from Sweetcake Creek to Melsing Creek, showing distribution of quartz stringers, in part mineralized, in schist and limestone.

with the massive limestone is impregnated with quartz veinlets. Sweetcake Creek occupies a similar position with respect to the contact of the siliceous schist and massive limestone.

IRON CREEK REGION.

The Iron Creek region which lies about 35 miles northeast of Nome, has produced a good deal of placer gold, though no very rich deposits have been found. There are also some copper and galena prospects within the district. The bedrock of the district consists chiefly of schist broken by broad belts of limestone which trend in a northwesterly direction. These features are indicated on the accompanying sketch map (fig. 13), but the details of the geology are far more complex than is indicated by this map. The limestone areas are broken by bands of schist. On the other hand, the areas mapped as schist include feldspathic and chloritic schists, as well as considerable areas of black slate and some bands of greenstone, which is of igneous origin. That the placer gold is derived from the schist and limestone contacts is clearly indicated by their distribution, as shown on the map.

Quartz is not a prominent constituent of the auriferous gravels, and quartz veins are not noticeably abundant in the country rock. The sulphide mineralization was decidedly of the disseminated type, except in the copper prospects. The relations of both quartz veinlets and sulphides to the country rock are much the same as those ob-

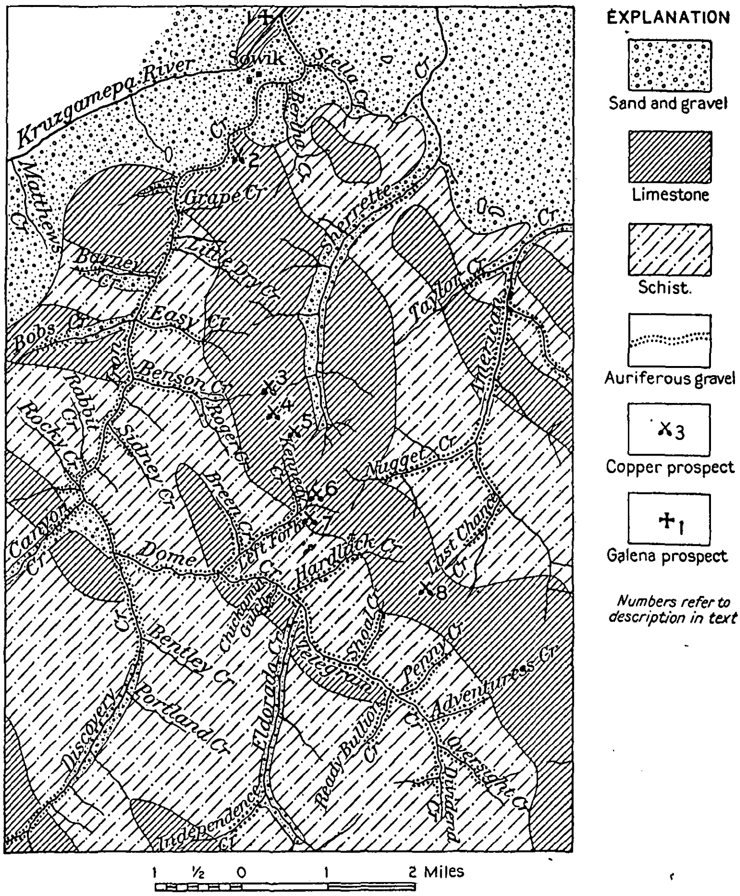

FIGURE 13.—Geologic sketch map of Iron Creek region.

served in the Council district, where schist interbedded with limestone and schist near its contact with heavy limestone were the most susceptible to shearing and the sheared zones offered the most favorable openings for the introduction of gold-bearing solutions. In the Iron Creek region the black slate seemed to have played a part comparable to that taken by the limestone. Both slate and limestone have acted as competent beds, and the schist adjacent to them shows what concentration of mineralization was observed.

Although quartz does not seem to be as abundant in the schist of Iron Creek as at other localities, considerable quartz is associated with the copper minerals in the limestone. This quartz is not known to be gold-bearing, neither is it known that the copper and gold mineralization are of the same age. The younger quartz veins, with which most of the veins in the schist can be safely correlated, have been found by Smith[47] to cut silicified limestone in the Solomon district, presumably similar to that which here carries the copper.

Benson Creek is an example of a creek which pans gold almost to its head. The gravels of the lower part of the creek have produced rather well, probably because the creek has reconcentrated the bench gravels through which it flows, but above the influence of the older gravels and where creek gravels can hardly be said to exist the loose wash surrounding boulders on the stream bed shows colors to almost every pan. The source of this gold is probably the schist zones which occur throughout the massive limestone, but proof is lacking.

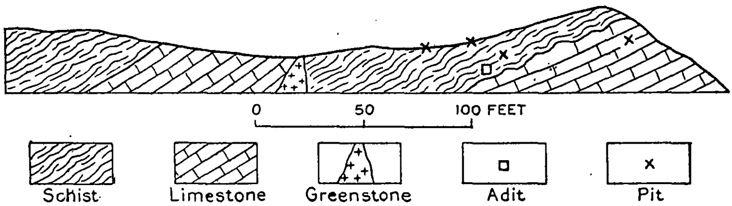

FIGURE 14.—Generalized sketch of exposures on east bank of Kruzgamepa River at Wheeler prospect.

The Wheeler prospect (fig. 13, No. 1) lies at the mouth of Iron Creek, and mine openings have been made in both sides of Kruzgamepa River. On the east bank several pits have been dug near a limestone and schist contact, and a short adit has been driven to cut the contact. Where not timbered the adit is now filled with ice, and almost no wall rock is visible and no ore was seen in place. The section exposed along the river bank near the prospect (fig. 14) shows at the north end 50 to 75 feet of blue marmarized limestone, succeeded to the south by 40 feet of quartz-muscovite schist, which in turn is succeeded by 50 feet of limestone, above which schist occurs. A greenstone, apparently intrusive, occurs at the lower contact of the upper limestone with the schist. The mineralization occurred along the contact of the lower limestone and the schist. The contact shows considerable deformation, the limestone and schist being infolded and the limestone rendered slightly schistose. The beds strike N. 70° W. and dip 10° N.

The schist at the contact shows an abundance of pyrite, but the limestone was only slightly mineralized, if at all. Galena is said to have been found in small quantities, both in the schist and in the

[47] Smith, P. S., op. cit. (Bull. 433), p. 142.

limestone. The ore consists of finely crystalline galena and pyrite in a gangue of quartz and calcite. Some chalcopyrite is also probably present, as malachite stain is seen in places.

On the west bank of the Kruzgamepa two "kidneys" of galena have been uncovered in a schistose limestone near its contact with a chloritic schist. One body of ore has been removed; a part of the other is still to be seen, but its relations to the inclosing rock are obscured by slide. The ore is exposed in an open cut 30 feet long driven northwest on the river bank and 15 feet above the stream. A shaft said to be 22 feet deep, sunk in line with the open cut, did not penetrate the overlying schist and exposed nothing but barren rock.

The mineralized zone is typical of a contact between limestone and schist along which adjustment has occurred. The limestone forms the footwall and adjacent to the schist is highly contorted, crenulated, and closely folded with schist. The limestone itself has become somewhat schistose at the contact, but the extreme deformation extends only 20 feet into the limestone, and beyond this zone it shows its normal crystalline, slightly schistose character. This zone seems to have been a locus of adjustment in the folding at this locality, as other contacts exposed along the river bank show less intense deformation of the limestone.

The ore is not well exposed but seems to have a lenticular form. The section seen was only a few feet in largest dimension. It seems to lie entirely within the limestone and is probably 30 feet or more from the contact. No schist was seen in immediate proximity to the ore.

The ore consists of finely crystalline galena with a little sphalerite and considerable pyrite in a gangue of quartz and calcite. The structural relations suggest that it may have been formed by replacement. Thin sections show that the sulphides occur both in the calcite and in the quartz in replacement relations, but some hand specimens show them as veinlets cutting quartz.

Mr. O. E. Wheeler, the owner, gives the following assay returns on samples of ore determined by Hoover & Strong, Denver. It is not known how the samples were taken: East side, lead 22.87 per cent, silver 20 ounces to the ton; west side, lead 14.2 per cent, silver 14.5 ounces to the ton.

Only a small tonnage of ore is in sight. The ore uncovered has been in disconnected masses along the zone of shearing and offers little encouragement for further prospecting.

The copper prospects of the Iron Creek district have been described by Smith.[48] No commercial ore bodies have been found in this

[48] Smith, P. S., U. S. Geol. Survey Bull. 345, pp. 242-243, 1908.

district, but in view of the mode of occurrence of the copper ores the prospects will be described in some detail.

The mineralization occurred in the limestone that forms the ridge east of Iron Creek. Mineralized rock has been found in a number of places on the ridge between the headwaters of Benson and Penny creeks. Prospecting has been confined to very shallow surface work, except at one locality where a 90-foot shaft has been sunk, and an adit driven. (See fig. 13, No. 4.) The shaft and adit were not accessible at the time of the writer's visit. Although the deposit has not been explored sufficiently to determine definitely the nature of the occcrrence, some of the features observed are worthy of record. The sulphide minerals, chiefly chalcopyrite and some pyrite, occur in quartz which has replaced the limestone and was probably introduced along the bedding planes of the limestone. Wherever observed the mineralized rock is banded, and the banding is conformable with and resembles in detail the banding of the limestone with which the siliceous rock is interbedded. Adjacent to the replaced limestone the normally blue limestone is usually bleached to pale blue or even white. The bleaching of the limestone may produce a banding of colors in the unsilicified and unmineralized rock. In many places beds of limestone show bleaching and recrystallization where no mineralization has taken place. That the bleached aspect of the limestone is due in some way to the process of mineralization and not to lithologic variation in the limestone itself is evident, as it is commonly seen adjacent to the silicified limestone and it is not continuous along the strike of a bed. As the quartz has probably been introduced along the limestone bedding planes the ore bodies can be expected to conform with the structure of the limestone country rock, but this inference can be proved only by underground exploration, though it is supported by all exposures of the silicified and of the bleached limestone where unmineralized. It is probable that here, as observed elsewhere on Seward Peninsula, the major adjustment in the limestone, where it occurs interbedded with schists and has been folded, has taken place along its bedding planes. This adjustment has made the bedding planes the equivalent of fractures and the easiest paths of circulation for later solutions. Fractures transverse to the bedding must also have formed, and exceptions to the bedded occurrence of the veins must be expected. Such an exception is seen near the head of Penny River, but all other exposures observed suggest strongly the bedded occurrence.

Shearing occurred at more than one horizon, and it is practically certain that more than one horizon is represented by the mineralized rock exposed here. The country rock is chiefly limestone, interbedded with which occur beds of schist 10 to 50 feet thick. None of the exposures show positively the relations of the shear zones to the schist. Schist that carries sufficient malachite to class it as an ore occurs, and copper-stained schist is common. Some specimens of schist ore were seen to carry a little sulphide. Although the silicified limestone observed is interbedded with normal limestone and none was seen at the schist contact, at least some of the openings were probably near the contact.

The silicified rock is of the replacement type that shows many small irregular cavities resulting from shrinkage. Thin sections of the rock indicate that replacement was complete and that quartz is the only gangue mineral. The quartz is shattered and strained and is traversed by sericite and chlorite in small veinlets. Polished specimens show chalcopyrite to be the principal and in places the only sulphide. It occurs in bands roughly parallel to the bedding of the limestone. The bands of sulphide are usually one-eighth inch or less, rarely an inch in width. Limonite surrounds and cuts the sulphides in the surface ores, which are the only ores available for examination, so that the original sulphide content and the relative proportions of sulphide to quartz can not be definitely stated. The fresh sulphide observed occurred within 5 feet of the surface and where seen probably did not form more than a small percentage of the ore. The most characteristic physical property of the ore is its banded structure, which is due to several factors, the sulphides occurring in the quartz and the iron oxide resulting from their decomposition, the shrinkage cavities of the quartz, the banding of the replaced limestone, and the copper carbonates that occur in the openings in the quartz and along the former bedding surfaces of the limestone. All these minerals are roughly alined in parallel arrangement and concordant with the bedding of the unmineralized limestone.

Sulphides of copper are not invariably present where there has been silicification of the limestone. In following one of these croppings along its dip, it may be found that the silica followed certain ill-defined channels along the limestone bedding, as a result of which it will grade laterally into limestone, also that the sulphide is present throughout some parts of the quartz rock and absent in others. The fact that it everywhere shows copper minerals at the surface is due to the presence of the copper carbonates, which will be found to disappear at depth. Although these suggestions are the least favorable that might be offered, they probably represent about what should be expected in developing such deposits. These deposits appear to be of the same type as those developed at Copper Mountain, in the upper Grand Central basin, to be described below.

Malachite is the most common of the oxidized ores, although azurite also occurs. Other secondary copper minerals seem to be absent. A polished surface of chalcopyrite ore shows sulphide surrounded and cut by limonite. Three types of oxidized ore occur—

schist, quartz, and botryoidal malachite. In the quartz-muscovite schist the malachite occurs along the cleavage surfaces and has the same relation to the quartz as the mica. In the siliceous ore carbonates occur as filamentary coatings of fracture surfaces, along planes of banding, and in open spaces through the rock. Some chalcopyrite is present with the carbonates. Crystalline malachite in radial structure with some botryoidal surfaces forms the highest-grade ore known to the miners. Iron oxide is an abundant constituent of all the oxidized ore.

The Wheeler copper prospect (fig. 13, No. 4) is at the head of Sherrette Creek on the east side and near the top of the mountain, near the head of Lula Creek, the north fork of Benson Creek. The development workings consist of several small pits and an adit 200 feet long, driven S. 50° W. to connect with a 90-foot shaft. The adit is now partly filled with ice and completely frosted over, so that no rock can be seen. It was driven in limestone and encountered no ore. The shaft was sunk on a cropping of malachite, which at the surface was 8 feet wide. At a depth of 25 feet schist was encountered, dipping south. The schist is stained by malachite and persisted in the shaft to a depth of 60 feet, where barren limestone was encountered, into which the shaft penetrated 5 feet. No drifting was done. The shaft is now filled with ice.

The only mineralized rock to be seen in place occurs at the open cut leading to the collar of the shaft. Here the limestone is closely folded, marmarized, and in places schistose. It was originally dark blue, but has been bleached white along certain zones and has a banded appearance. Schist infolded in the limestone is stained with malachite and contains some stringers of quartz.

Assay returns on ore from this property shipped to the Tacoma smelter are given by Mr. Wheeler, as follows: The surface malachite, taken above a depth of 20 feet in the shaft, assayed gold, none; silver, 0.33 ounce to the ton; copper, 35.68 per cent; iron, 7.60 per cent; silica, 15.40 per cent. About 8 tons of this material was shipped. Schist ore taken below a depth of 25 feet in the shaft assayed gold, 1.82 ounces to the ton; silver, 5.16 ounces to the ton; copper, 17.18 per cent. About 2½ tons of this ore was shipped. Another shipment of 14 tons was made, but no assays of it are available.

Nothing can be seen of the lode from which this ore was taken, but Smith[49] describes it as a zone of mineralization 5 feet wide in schist. It appears to occur in a schist layer in the limestone. A quartz vein striking north was observed near this copper locality. The quartz is iron stained, but no work has been done on it, so its size and relations are not observable on the talus-covered slope. Two open cuts on the saddle at the head of Benson Creek exposed nothing but lime-

[49] Smith, P. S., U. S. Geol. Survey Bull. 345, pp. 242-243, 1908.

stone. The limestone is blue, coarsely crystalline, and banded by zones of white marble, one-quarter inch to 3 inches wide. It is slightly schistose and badly fractured. The dip is almost vertical. A fault striking N. 25° E. is exposed in one pit. The limestone south of the fault surface is much shattered.

Near the top of the mountain at the head of Benson Creek, south of the saddle (fig. 13, No. 3), a drift has been made in silicified limestone, which shows copper metallization. The workings, which are but 8 feet deep, give the best exposure of the copper ore seen in the district. At the face of the drift the following section is exposed:

Section at face of drift at head of Benson Creek.

	Feet.
Blue limestone	6
Silicified limestone with no copper	1½
Copper ore containing quartz and copper sulphide and carbonate	5
Limestone	1
Blue limestone.	

The mineralized rock is a silicified limestone, the bedding of which is still apparent and conformable with the overlying blue limestone, which strikes N. 10° E. and dips 5°–10° E. Close folding of the limestone is shown in the trench leading to the pit. The face of ore as exposed is an alternation of roughly parallel bands of malachite, quartz, sulphides, and iron oxides. The layers of ore minerals are discontinuous and are interspersed throughout with quartz, without order of succession. They vary from minute films to layers half an inch in width. The sulphide is chiefly chalcopyrite, which is surrounded by iron oxide.

The ore body seems to be related to the bedding of the limestone. It occurs with limestone on both footwall and hanging wall, and there is no indication of vein or lens form. However, it has not been opened along the dip, and this relation is not proved. No schist is exposed, but the folded limestone seen in one trench suggests the usual occurrence at the limestone and schist contact. The section exposed along the ridge between this locality and the shaft is made up of limestone, including a few schist zones 50 to 100 feet thick. The sulphides are clearly related to the quartz, which was probably injected as tiny veinlets along closely spaced bedding shear zones and replaced the adjacent limestone. On the top of the hill, half a mile to the south, four pits have exposed silicified limestone, but only a trace of mineralization was observed. The silicification is here clearly related to shearing in the limestone, as no schist is present.

Three openings have been made on a copper cropping at the head of Sherrette Creek, on the east side of the ridge (fig. 13, No. 5). The pits are shallow and filled with débris, so that no structural data can be obtained. Mineralized quartz and schist occur on the dumps. The mineralization is of the same type as that in the Wheeler prospect.

Two 20-foot cuts have been made in limestone on the west slope and near the top of the ridge, at the head of Left Fork (fig. 13, No. 6). In the more easterly one a little quartz-malachite ore is exposed, some of which carries sulphides. Little can be seen of the structural relations, but the ore appears to conform with the bedding. The only relation evident is that of copper to quartz. The quartz shows many openings, some of which are lined with projecting crystals. The copper carbonate occurs chiefly as fillings of the cavities and coatings on fractures.

About 100 feet northwest of these cuts a pit uncovers a quartz zone conformable with the bedding and unaltered limestone. The quartz is probably continuous with that at the cuts, but here the open texture of the quartz is less evident and almost no malachite is seen—a fact which points to irregularity of mineralization along the quartz zones, dependent upon the texture. This statement applies to the oxidized ore only. As is seen elsewhere, the sulphide content, though irregular, is not related to the open texture.

On the point of the hill near creek level, just above the forks of Left Fork (fig. 13, No. 7), an opening in limestone exposes carbonate ores of copper. Both azurite and malachite are present. The cut is very small, exposing a face of about 10 by 5 feet, so that few structural data are obtainable: The limestone strikes N. 20° E. and dips 25° E. No schist is exposed. The relation of quartz to limestone here is somewhat different from that seen elsewhere. A lens-like mass of quartz lies in general at a slight inclination to the bedding of the limestone. Several small stringers and apophyses from the lens cut the exposed face. The limestone and quartz contact is in places clean-cut, blue massive unaltered and unmineralized limestone adjoining the vein. Elsewhere the limestone near the vein is silicified and the original banding preserved. All the copper minerals seen are associated with the quartz and are oxidized. They coat fractures and occur as a drusy filling of cavities in the quartz.

Although the banded character shown by the ores of the Wheeler copper prospect is evident in some of the material here, the relation of the quartz is more of the vein type. It suggests that the quartz has followed fissures which in general were openings along beds of limestone but in places cut across the limestone beds. The replacement of the limestone was incidental to the introduction of the quartz. Several shallow pits have been made along the ridge southeast of this locality. They have exposed the typical quartz rock, but it shows little or no mineralization.

Several open cuts have been made on a strong showing of the quartz on the west side of the ridge about midway between the headwaters of Left Fork and Hardluck Creek, but there is hardly a trace of copper mineralization. The character of the quartz body has not changed, the open texture of the quartz and the well-terminated crystals lining cavities are the same, and some decomposed sulphide is disseminated through the rock, but the copper minerals seem to have largely disappeared. The limestone here is shattered and almost schistose. It strikes N. 30° W. and dips south. The exposures show nothing of the relations of the quartz and limestone.

Just south of the saddle between Shoal and Last Chance creeks a 6 by 8 foot shaft 10 feet deep has been sunk on an outcrop of quartz (fig. 13, No. 8). Although exposed for only a few feet along the strike it appears to be a distinct vein and in this respect is different from other exposures. The vein is 5 or 6 feet wide, strikes N. 50° W., and dips west. The limestone 100 yards to the east strikes N. 70° W. and dips 20° S. At its contact with the vein the limestone is altered to a calcareous schist for a width of a few inches. Both schist and limestone show a little sulphide mineralization adjacent to the vein. The quartz is mineralized by decomposed sulphides, some of which were probably chalcopyrite. Very little copper stain is present, however, and the vein is chiefly a slightly iron-stained bull quartz. The silicified limestone does not occur here, the limestone being calcareous to the vein walls.

About 200 yards to the south, at the head of Penny Creek, several openings on quartz in limestone show only very slight copper stain. The exposures do not show the relations. The copper almost disappears southward along the ridge. No further openings or croppings were observed.

On the east bank of Iron Creek about a mile above the mouth of Bertha Creek (fig. 13, No. 2) a small open cut exposes a lode of the type occurring on the ridge at the head of Benson Creek. The material is silicified limestone containing a little sulphide and some malachite stain. The lode occurs in the blue limestone but is poorly exposed and not well defined. It is about 3 feet wide where seen.

About 200 feet north of this locality a vein of coarsely crystalline calcite has been opened. The calcite is cut by veinlets of quartz and contains fresh pyrite in abundance. Some pyrite also occurs in the quartz veinlets. The relations of the vein are not exposed. Both schist and limestone occur on the dump and suggest that the vein is at or near to the contact.

COPPER MOUNTAIN.

Some copper-bearing rock has been found on the two slopes of Copper Mountain, whose drainage is carried southward into Nome River and northward into Kruzgamepa River. This area lies about 25 miles north of Nome. The general features of the geology are shown on the accompanying map (fig. 15), which is based on Moffit's survey.[50] A broad belt of schist, locally including beds and lenses of limestone, forms the country rock of the mineralized area. To the south the schist is overlain by heavy limestones which include some minor beds of schist. On the lower northern slope of the mountain there is a small area of gneissoid granite, which was intruded in the schist.

So far as it could be determined the copper mineralization was of the same type as that on Iron Creek, already described. The zones of mineralization occur in bleached and in places silicified beds or lenses of limestone which are interlayered with the schist. In these

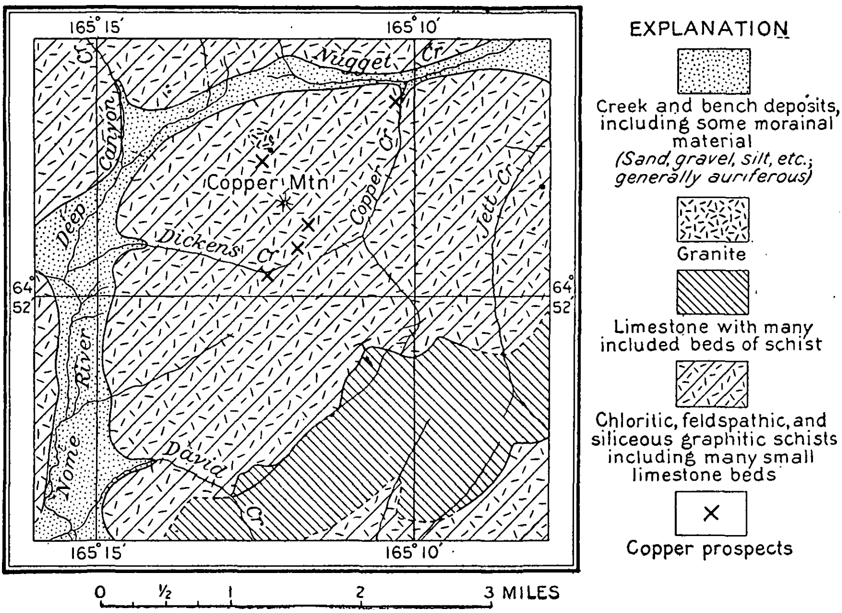

FIGURE 15.—Geologic sketch map of Copper Mountain area.

zones sulphides occur in association with quartz. The quartz is of open texture, and shows shrinkage cavities. The most prominent feature of the ore is its banding, which is due in part to the preservation of the original limestone bedding and in part to the disposition of the ore minerals.

Microscopic examination of the bleached but apparently unsilicified and unmetallized limestone shows it to be practically all calcite. Muscovite occurs in small amounts along bedding planes. Veinlets of quartz that are parallel and oriented with the micas are numerous. Angular crystals of quartz occur through the calcite and are especially abundant near the veinlets. The relations of the quartz suggest

[50] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, 1913.

that it was introduced along cleavage surfaces and replaced the limestone. In the silicified limestone in which copper sulphides occur the replacement is complete, and quartz, with a little mica, forms the gangue of the ore.

Malachite and azurite are the most abundant ore minerals, as the workings have been confined to the oxidized zone. Sulphides occur, however, within a few feet of the surface. Pyrite and chalcopyrite are about equally abundant. Galena is present in small amounts at one of the shafts on Dickens Creek. Bornite is common as an associate of chalcopyrite and in places is the only copper sulphide in the ore. The amount of mineralized rock that might be classed as ore and the details of the occurrence of the ore can not be determined, as the workings are all inaccessible.

The occurrence near the north point of Copper Mountain is of interest in that it is one of the two prospects in southern Seward Peninsula which are in the vicinity of recognizable intrusive granite. A small body of sheared biotite granite crops out on the slope below the tunnel (fig. 15). The granite is rather finely crystalline but shows porphyritic and chilled marginal phases. Small dikes of dense finely crystalline light-green rock cut the mass. Both dikes and granite are cut by later quartz veins. The contact is not exposed, but blocks of limestone in contact with the chilled phase of the granite were seen as float. The limestone is marmarized, and pyrite occurs here and there at the contact, but the rock shows no other evidence of metamorphism. The granite is intruded in schist that is in contact with the silicified limestone in which the mineralization occurred. About 50 feet of schist lies between the granite outcrop and the mineralized zone. No direct relation between the igneous rock and the mineralization was observed. The facts that the mineralized zone is associated with uncrushed quartz and that the sheared granite is cut by undisturbed quartz veins suggest that movement affecting both the sedimentary contacts and the igneous intrusive prepared the openings which are now occupied by the mineralized quartz and the quartz veins, respectively.

On Copper Creek about a quarter of a mile above the railroad several openings have been made in a limestone bed which shows zones of alteration and some copper mineralization. The country rock here is schist, with which occur beds of limestone 50 to 100 feet thick. A fall is formed where the creek crosses the contact and affords an unusually good exposure of the alteration and mineralization of the limestone. The limestone, normally blue, is bleached for a thickness of 12 feet to white or pale bluish white. In places this alteration affects the rock in zones and gives the limestone a banding parallel to the bedding. Both the bleached and the unbleached limestone are coarsely crystalline, and some of the bleached rock resembles pure calcite. Distortion of the limestone along the contact with the schist was not observed at this exposure. Several zones of schist a few inches thick are interbedded with the limestone, but the rock itself is massive. Two openings have been made in the altered zone at the fall. On the west bank of the creek a 10-foot incline and an 8-foot shaft have cut into but not across the zone. The rock shows little silicification and no copper minerals. On the east bank, 200 feet away from the first opening, an incline has been driven on the same zone. The limestone dips 28° S., and the incline follows the dip. At the time of visit ice filled the opening within 20 feet of the surface. The rock here is banded blue and white, and the bands are from a few inches to a foot or more in width. As a whole it is little silicified, but there are two zones of entirely silicified rock conformable with the bedding. They are 3 and 5 inches wide and separated by a foot or more of unsilicified rock. The quartz rock has a banded character, due in part to the white and blue colors, in part to copper carbonate, and in part to bornite, which with the carbonate seems to occur along former planes of lamination. The mineralized rock appears to be the result of a replacement of limestone and the silica to have been introduced along the bedding planes.

The almost complete absence of quartz in the western prospect indicates a very erratic distribution of this mineral. The presence of unmineralized quartz indicates further restriction of the sulphide mineralization. Where sulphide minerals of this type have been observed, they occur in silicified portions of bleached limestone. The bleached limestone, however, is not everywhere silicified, and the quartz is not everywhere metallized. The next overlying limestone shows only a very little copper stain, although its altered basal portion is as prominent as the limestone just referred to. The upper contact of this bed of limestone is also altered, but without being silicified, so far as observed. There are certainly two zones of alteration here, and probably three, as no surface indications of faulting can be observed.

The neighboring schists are highly mineralized and are cut by veins of the quartz-calcite type. One quartz vein 2 feet wide can be traced for a quarter of a mile on the upper creek. The quartz-calcite veins show sulphide mineralization both in the quartz and in the calcite.

Work has been done on a similar copper showing on the divide between Copper and Dickens creeks. A number of pits, trenches, and shallow shafts have been made on a zone of bleached limestone, which is as much as 300 feet wide, is lenticular in outline, and extends in a N. 40° E. direction for a distance of a quarter of a mile. The openings are now caved or filled with water, and no exposures of ore in place can be seen. Moss covers the saddle and hillside, so that the stratigraphic relations are obscured, and only mineralized rock from the dumps is available for examination. Chalcopyrite, bornite, and pyrite are the most abundant sulphides. Galena occurs in small amounts at one shaft. Azurite and malachite are present with the sulphides. The sulphide and oxide minerals occur in a roughly parallel arrangement, giving the ore a banded appearance.

This zone is too high stratigraphically to be correlated with the zones of Copper Creek. The circumscribed nature of this type of mineralization is emphasized here by the apparent elliptical form of the area of altered limestone.

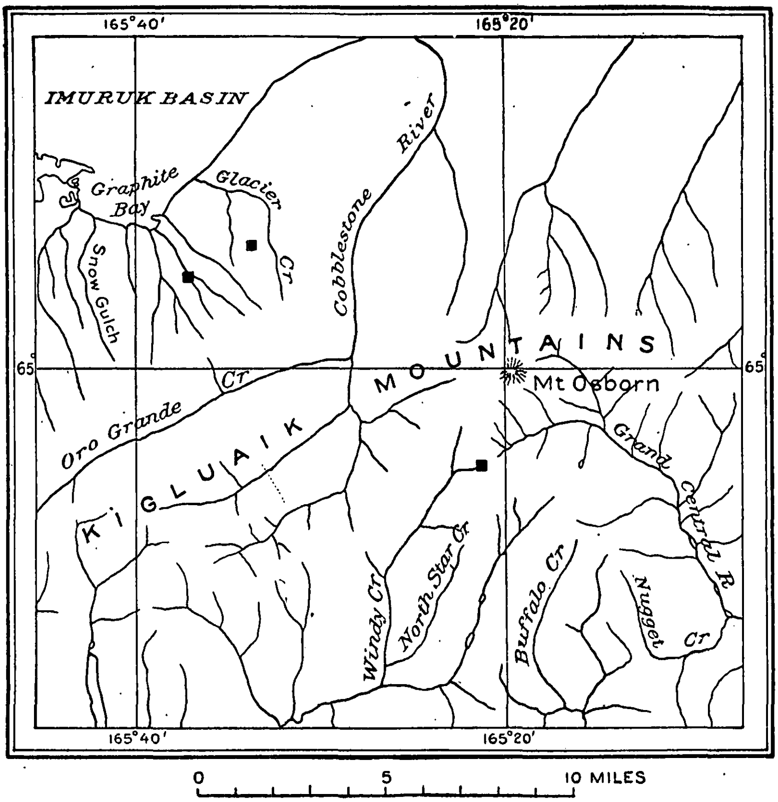

FIGURE 16.—Map showing location of graphite deposits (■) in the Kigluaik Mountains.

GRAPHITE DEPOSITS IN THE KIGLUAIK MOUNTAINS.

Graphitic schists are common in the Kigluaik Mountains, and in many places the graphite is sufficiently abundant to warrant their investigation as possible commercial deposits. Several hundred tons of graphite has been mined on the north slope of the mountains, where commercial ore bodies have been developed on two properties only a few miles from tidewater at the Imuruk Basin. (See fig. 16.) Development work on these two properties is at present suspended. Harrington[51] has described these deposits as occurring in lenses associated with the schist and gneiss that form the country rock of the northern slope of the Kigluaik Mountains. Such graphitic deposits have been traced for several miles west of Cobblestone River on the outer slope of the mountains and are reported to occur farther in the range. Considerable work has been done on the properties, but most of the graphite shipments have been made from the eastern property, owned by the Alaska Graphite Co., which has built a wagon road to tidewater. The second group of claims is owned by the Uncle Sam Alaska Mining Co. The following description of these deposits is taken from Harrington's report:[52]

The lenses of graphite occur in association with quartz schists that carry biotite, but garnetiferous schists that carry some calcite are also locally present. Some of the quartz schists have the appearance of beds of metamorphosed sandstone. Tourmaline was noted in small grains in the graphite at one locality. Granitic rocks appear to make up a portion of the core of the range. The general trend of the schists in which the graphite occurs is a little north of west and the dip is 60°–75° N. Locally there are two or three series of graphite lenses which are parallel in strike and dip, but it can not be positively stated, without further very detailed studies, that they represent more than one horizon, which may have been repeated by faulting or close folding.

The topographic situation and nearness to water transportation have favored development work at these deposits, in comparison with those which are said to occur for several miles eastward, extending along the front of the range beyond Cobblestone River and appearing on the hill slopes or in the stream valleys which are incised into the range.

* * * * * * *

There appears to be an opportunity for the development of a large amount of graphite from these deposits. Transportation problems are relatively simple. If a sufficient tonnage is mined aerial trams, possibly of a gravity type, might be used from one or both properties. For smaller tonnage good roads could be easily constructed for team or power haulage, and the power required for hauling loads would be small on account of the generally uniform downhill slope to the shipping point. Graphite Bay affords a good shallow harbor, for numerous small coves and islands give protection from storms.

If a mill should be erected at either property hydroelectric installations would probably prove the more economical for summer operations, power being derived from some of the small streams which cross the claims. For winter operations other power would be necessary.

Graphite deposits also occur south of the crest line of the Kigluaik Mountains, where they were long ago found by Moffit,[53] but not being as accessible as those described above, they have attracted but little attention. Such deposits are found in the upper part of the Grand Central basin, where they have an eastern trend. The best

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[51] Harrington, G. L., Mineral resources of Seward Peninsula: U. S. Geol. Survey Bull. 692, pp. 364–366, 1919.

[52] Op. cit., pp. 365, 367.

[53] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, pp. 135–136, 1913.

deposit seen in that region occurs on the West Fork of Grand Central River in the schist which overlies the limestone forming Mount Osborn and in which the valley of West Fork is cut. This schist probably belongs to an older series than those which are described in connection with the other deposits and are confined to the mountain area. It is essentially a siliceous biotite schist and is intruded by many igneous sills and dikes. In general it strikes N. 80° E. and dips 15°–25° S.

The best exposure of the graphite-bearing beds occurs along the divide between West Fork of Grand Central River and Windy Creek. The schist includes quartz-biotite, garnet, and graphitic varieties. Some limestone in thin beds and numerous intrusive sills and dikes of granitic rock complete the section.

Most of the graphite occurs as small flakes disseminated through the schist. It is locally segregated in nests of ¼-inch size in the rock, but usually its distribution through the rock is uniform. At some horizons the flakes of graphite are parallel and give a schistose structure to the rock; at others they occur without uniform orientation. The richest of this material is essentially quartz-graphite schist. Where graphite occurs with biotite it is not always easy to distinguish the two in hand specimens, and the material appears to be of much better quality than it really is. The biotite schist is the most prominent member of the series.

BISMUTH DEPOSIT.

A quartz vein containing a little disseminated bismuth sulphide is exposed in the stream channel of the east fork of Charley Creek, a tributary from the south to upper Stewart River. The deposit lies about 25 miles due north of Nome. It does not appear to be of commercial value, so far as can be determined from the exposures, but a description is included here because the occurrence of vein bismuth is unknown elsewhere in the peninsula. The country rock is schist.

The development workings consist of open cuts on both sides of the creek, which expose the vein for a distance of about 50 feet along the strike and 10 feet in depth. Two parallel quartz veins 10 and 5 inches wide, striking N. 80° W. and dipping 50° N., are separated by a foot or more of schist. The quartz is of the open-textured type and shows numerous cavities lined with well-terminated crystals. Microscopically the vein is made up of quartz with a little white mica. The veins have been intruded along joint planes in the chloritic schist country rock, which strikes east and dips 30° S. The wall rock is quartz-muscovite schist containing considerable chlorite and some biotite. A little graphite and pyrite are also present. The veins can not be traced beyond the creek bottom, the valley sides being covered by moss and talus, and they are exposed here only because the creek has cut a narrow gorge in this part of its course.

No ore was seen in place. A small quantity of mineralized quartz on the dump contains bismuthinite, occurring in tiny veinlets through the rock. Cross veinlets concentrated here and there form dark patches in the white, opaque vein material. There is no means of estimating the sulphide content of the vein, as the portion now exposed was not seen to contain any. The mineralized material on the dump contains only 1 or 2 per cent of sulphide, and the metal content of the vein is probably very small. The vein has been reported to contain platinum in considerable amounts, but reliable assays made for the Geological Survey show no trace of platinum.

ANTIMONY DEPOSITS.

Antimony in the form of stibnite is rather widely distributed on Seward Peninsula.[54] It occurs at several localities in the vicinity of Nome, in the Manila-Lost Creek area, described below, on Big Hurrah Creek in the Solomon district (p. 204), in the York district,[55] and at the Omalik mine, in Fish River basin.[56]

The deposits in the Manila-Lost Creek area have thus far proved to be of the most importance. A number of antimony-bearing lodes have been found in this area, which lies about 20 miles north of Nome. Here the southward drainage goes into Nome and Snake rivers, and the northward drainage into Stewart River. As shown on the accompanying map (fig. 17), which is based on Moffit's survey, the country rock consists of a great series of schists, with some interbedded limestone, which is overlain by a heavy limestone formation that also includes some beds of schist. These rocks are cut by a few granite stocks and dikes.

In the vicinity of Manila Creek a number of antimony-quartz lodes, some of which are gold-bearing, have been prospected. At the Hed & Strand mine, on Dahl Gulch, a tributary of Lost Creek, and at the Sliscovich mine, on Manila Creek, considerable development work has been done and some antimony ore has been produced. The Hed & Strand property has been described by Mertie,[57] and the Sliscovich by Chapin.[58] Little or no progress has been made since their visits. A number of other prospects have exposed ore between Cold Creek and Manila Creek and on the divide between Manila and Hobson creeks, but the workings are shallow, and except

[54] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, pp. 50, 59, 1916.

[55] Knopf, Adolph, Geology of the Seward Peninsula tin deposits: U. S. Geol. Survey Bull. 358, 1908.

[56] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 131-133, 1911.

[57] Mertie, J. B., jr., Placer mining on Seward Peninsula: U. S. Geol. Survey Bull. 662, p. 436, 1917.

[58] Chapin, Theodore, Lode development on Seward Peninsula: U. S. Geol. Survey Bull. 592, p. 403, 1914.

for ore on the dump show nothing concerning the occurrence of the antimony.

The ores of this locality are typical of most of the antimony ores of the peninsula. In the area examined the stibnite is commonly associated with the later quartz veins. Kidneys of stibnite accompanied by very little quartz have been found along shear zones in

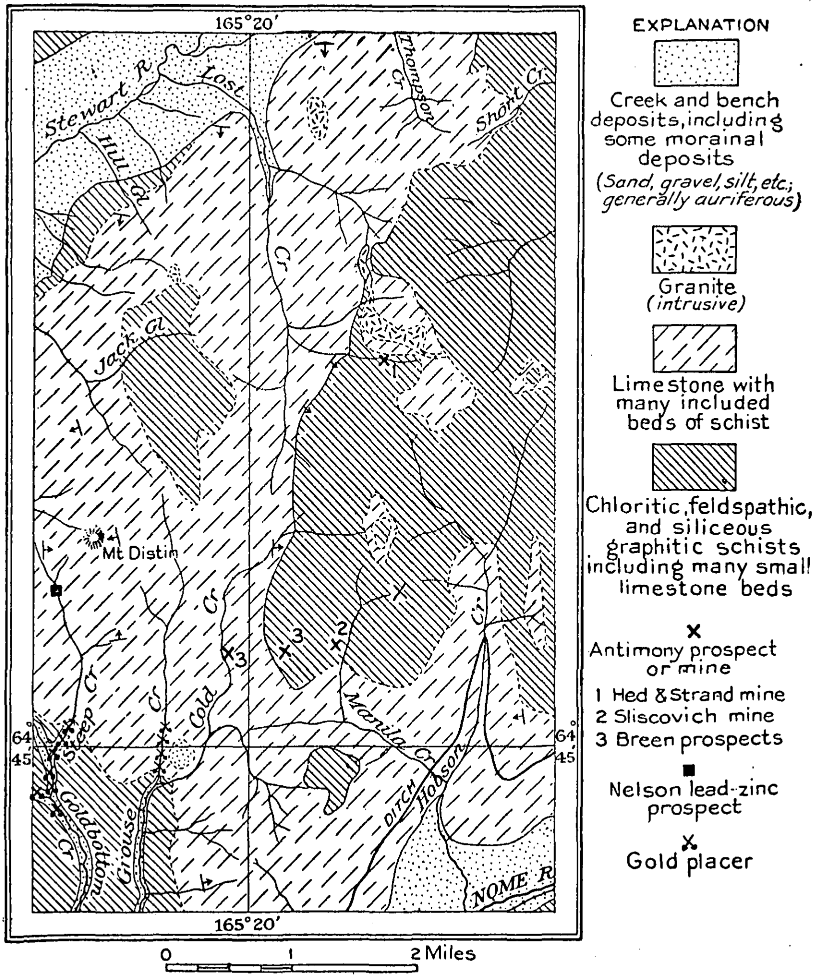

FIGURE 17.—Geologic sketch map of Manila-Lost Creek area.

schist at the Boulder lode on Waterfall Creek (p. 231), and in the Winsted tunnel on Anvil Creek (p. 238), but the ore bodies are small.

Where associated with the quartz veins the stibnite seems to have been introduced since the formation of the veins. Apparently after the intrusion of the quartz veins movement continued to take place along the vein fissures and they were reopened and the veins shattered. Antimony-quartz solutions were then introduced.[59] At some localities the stibnite occurs as irregular bodies between the vein and its schist wall and as nests and stringers in the vein itself, but at most localities it is present only as veinlets in the quartz.

The stibnite is usually accompanied by some pyrite and a variable amount of contemporaneous quartz. In the purest specimens the stibnite occurs as distinct acicular crystals, some of them an inch or more long, and the quartz is present as well-formed but smaller crystals with good terminations. In the lower-grade ore the stibnite is finely crystalline and quartz forms most of the rock. Gold is known to be present with the antimony at the Sliscovich mine and at several deposits on Anvil Creek.

The deposit at the Hed & Strand mine is of special interest in connection with the genesis of the ores because of its occurrence in the immediate vicinity of intrusive granite. The granite is sheared and resembles the sheared granite occurring in the mountains to the north. It consists of orthoclase and a very little plagioclase, quartz, considerable muscovite, a little biotite, and abundant chlorite. Magnetite, zircon, apatite, and titanite are present as accessories. The texture is granitic, medium coarse, and uniformly crystalline. The contact is nowhere exposed, but prospect pits near the contact expose altered limestone and in one place a little antimony.

In one pit within 100 yards of the contact the limestone is altered to a dense light-green rock composed of epidote, cordierite, quartz, muscovite, and calcite. On the divide between Dahl Gulch and Dorothy Creek a pit near the contact exposes a similar rock, but it contains amphibole. In some specimens the amphibole forms 50 per cent of the rock and occurs in crystals half an inch in length. Microscopically the rock is composed of green hornblende, epidote, zoisite, cordierite, muscovite, quartz, zircon, titanite, and calcite. Neither of these rocks, which appear to be products of contact metamorphism, contains any stibnite, although some pyrite is present. In another pit, within 100 feet of the contact, the limestone is bleached and coarsely crystalline. The altered limestone is partly replaced by quartz. Stibnite occurs in veinlets of one-quarter inch to microscopic size, cutting both calcite and quartz of the altered rock. Pyrite is abundant, and malachite is present in small amount. Both occur in or coating fractures. Calcite veins are numerous in the limestone, and one vein was seen to contain a crystal of stibnite 1 inch long.

Although the data obtainable do not afford definite proof, it is probable that the epidotized limestone is the result of contact metamorphism. It is not certain, however, that the stibnite is in any way related to the granite. Stibnite is not seen to occur with the

[59] This interpretation of the facts has already been made by Brooks (Bull. 449, p. 52, 1911).

contact rock. It is present with the silicified limestone but is of later origin than the alteration of that rock. It is probable that an opening was formed at the granite contact, along which the stibnite solutions entered. Further evidence that the antimony mineralization was not related to the granite is found in the structural relations. The granite has been badly sheared. The age of greatest movement in the rocks of the region antedated the formation of the quartz veins, later movement shattered these veins, and the stibnite was then introduced. Some movement has occurred along the veins since that time, but it has probably been slight, as even the soft stibnite ore has been little affected by it. The time of antimony mineralization would therefore seem to be much later than the intrusion of the granite.

The structural features observed in the Sliscovich and Hed & Strand tunnels, as well as the strike of these two well-defined lodes, indicate a parallelism with the dominating structure of the Kigluaik Mountains to the north. These features are probably related to the later deformation of the Kigluaik rocks. The smaller features of this period of folding probably determined the openings along which antimony mineralization took place.

The Hed & Strand antimony mine is on Dahl Gulch, a tributary of Lost Creek, which empties into Stewart River (fig. 17). A 250-foot tunnel has been driven near creek level in a direction S. 40° E. Drifts have been run 145 feet southwest and 520 feet northeast along the main vein, which is intersected 90 feet from the entry. At 200 feet from the entry a drift has been run 190 feet northeast. A winze has been sunk in the tunnel 60 feet from the entry, and a raise driven from the 520-foot drift. Some stoping has been done on the vein, and numerous surface pits and trenches have been dug in the vicinity of the mine. Shipments of ore were made in 1915 and 1916, totaling 106 tons, and a few tons remain on the dump.

At the time of the writer's visit little could be seen of the ore relations. Stibnite has been mined only from the main vein, where it occurred in shoots. The shoots encountered by the present workings have been stoped out, so that only the least productive part of the vein is now exposed. The vein strikes N. 65° E. and dips 50° NW. According to Mertie,[60] the vein where intersected by the tunnel was 4 feet thick and consisted of white quartz and stibnite. The stibnite occurred as a body 2 feet thick along the footwall. As exposed along the drift the vein shows repeated pinch and swell. Where not stoped the vein is present only as a thin stringer and in places seems to disappear entirely. Near the end of the northeast drift the quartz has a gray color, due to finely crystalline stibnite, occurring in tiny veinlets through it. Elsewhere it contains only pyrite in veinlets.

[60] Mertie, J. B., jr., Placer mining on Seward Peninsula: U. S. Geol. Survey Bull. 662, p. 437, 1917.

At the end of the northeast drift a 2-inch quartz vein intersects the drift at an angle near 90°. An eighth of an inch of pyrite occurs between the quartz and the wall rock. Specimens of massive arsenopyrite, said to come from this locality, were shown to the writer and are reported to be silver-bearing. This veinlet does not seem to be related to the main vein. In the southwest drift near the adit a small amount of ore remains at the edge of a stope. Two types of ore are present—quartz vein material cut by veinlets of stibnite and acicular stibnite including crystals of quartz. The quartz is here frozen to the footwall and is 2 inches thick; 1 inch of gouge separates the quartz from 1 inch of stibnite, and 3 inches of gouge occurs between the stibnite and the hanging wall. The stibnite is evidently later than the quartz vein and has been introduced along the hanging wall, filling fractures in the quartz vein and occupying open spaces between the vein and the hanging wall. Later movement along the vein has broken the contacts between the quartz and stibnite and between the stibnite and the hanging wall.

The wall rock is chlorite schist, and the hanging wall is everywhere slickensided. At the end of the southwest drift the footwall is altered to sericite schist and is highly mineralized by pyrite. This alteration was not seen to be common.

The drift running northeast at 200 feet from the entry exposes little. It follows a stringer of quartz one-fourth inch to 4 inches wide. The walls are slickensided and in places show gouge. No antimony was seen. At 30 feet from the adit the drift intersects an 8-inch quartz vein, which is offset 2 feet in crossing the drift.

A zone of antimony-quartz mineralization appears to extend from the divide between Hobson and Manila creeks to Cold Creek. The relations of the lodes to the geology can be made out only at the Sliscovich mine, for little can be learned from the surface. The steep slopes are covered with coarse talus of chlorite and feldspar schist; the gentle slopes with moss. Quartz float is abundant through the talus, and a number of veins are probably represented.

At the head of the right fork of Manila Creek a quartz vein not fully exposed but apparently several feet wide strikes S. 80° E. and dips 40° S. It was located by Joe Sliscovich as a quartz lode. No evidence of mineralization was observed, and almost no work has been done on the property.

Just east of this exposure, along the strike of the vein, several pits have exposed quartz which shows mineralization and structure similar to those of the copper ore of Iron Creek and Copper Mountain. It is an open-textured banded quartz rock which contains abundant sulphide, chiefly pyrite, and some malachite stain. The source of this material is not clear. It is not exposed well enough to indicate whether it is a vein or rock in place. Its isolated occurrence suggests that it might be a drift boulder derived from the ridge above.

The ridge at the head of the right fork of Manila Creek consists of limestone underlain by schist. Several pits along the contact zone expose bleached limestone and in places a calcareous muscovite schist stained by malachite. The copper stain is associated with the mica, and the rock is similar to the schist ore of Iron Creek. The quartz rock referred to above may have originated along this contact, although the bleached limestone exposed at the contact is not noticeably silicified or metallized.

A hundred yards southeast of the copper-stained rock on the ridge several openings have been made on antimony ore. The veins were not exposed at the time of visit, but ore on the dump shows that the mineralization was essentially the same as at the Hed & Strand mine, the rock consisting of quartz cut by veinlets of stibnite. The country rock is chlorite schist.

The Sliscovich antimony-gold mine is near the head of Manila Creek (fig. 17). Details of the occurrence are reported as follows by Chapin,[61] who visited the property in 1913:

This property was staked in 1905. The vein, which strikes N. 60° E. and dips 45° NW., was traced on the surface for over half a mile, nearly across the basin of Manila Creek. Besides a number of prospect pits two openings have been made to develop the lode. A short distance below the point of discovery a 50-foot adit was driven to crosscut the lode, but no further work was done at this place. The main opening is at an elevation 100 feet lower. There an adit was driven 315 feet to the lode, which was opened by an inclined shaft for 100 feet.

The lode is composed essentially of dull, opaque quartz and stibnite, the sulphide of antimony, in approximately equal amounts, although slight variations in the proportions of the two minerals appear from place to place. Near the surface the antimony predominates, and in places nearly pure stibnite occurs in small bunches. A number of assays and analyses have been made on samples of the ore, all of which show rather constant antimony, gold, and silver. An analysis made on a small shipment of ore said by the owners to have been obtained by accurate sampling of the vein was submitted for chemical determination and showed the following:

Gold and silver not published.

Antimony (Sb)	35.05
Sulphur (S)	13.79
Silica (SiO_2)	48.80
Molybdenum (Mo)	None
Qualitative arsenic (As)	None
Wet lead	Trace
	97.64

Lime and magnesia present but not determined quantitatively.

No development work has been done on the property since Chapin's visit. In 1915 the high price of antimony induced the mining of the antimony portion of the vein. A stope was begun about 30

[61] Chapin, Theodore, Lode developments on Seward Peninsula: U. S. Geol. Survey Bull. 592, pp. 403–404, 1914.

feet from the bottom of the shaft, driven 30 feet to the north and 40 feet to the south along the vein, and extended within 25 feet of the floor of the adit. Only rock containing high percentages of stibnite was removed, and the waste incident to such mining was dumped into the shaft. The stopes were not well timbered, and the roof is sloughing, so that only that part of the vein at the upper limit of the stope can be seen.

Where the vein is intersected in the adit it is only a few inches wide. At a depth of about 25 feet in the shaft it swells, and this is the portion that has been removed. At one place it was seen to consist of 13 inches of stibnite and 32 inches of quartz. It appears to be a compound vein similar to the Hed & Strand vein, consisting of a quartz portion on the hanging wall through which occur veins and nests of stibnite, and a stibnite portion on the footwall in which the stibnite includes some quartz. Gouge occurs on both walls and between the two portions of the vein.

The relative proportion of the quartz and stibnite phases of the vein varies from place to place. The stibnite portion is said to thin out entirely in places, but the quartz portion to persist. The quartz phase may show almost no stibnite, a little, or much. Some nests of very pure coarsely crystalline stibnite occur through the vein. The antimony mineralization was clearly later than the introduction of the gold-bearing quartz vein.

Few structural data can be had from the working, due to timbering, frosting, and sloughing of the walls. A number of fractures can be made out, striking N. 30°–60° E. and dipping 45°–80° W. Gouge marks some of the surfaces, and several are filled by thin seams of quartz. One fault surface, almost horizontal, extends for 150 feet. The wavy character of the surface is noticeable. Here as elsewhere irregularity seems to mark the fractures in schist and is reflected in the pinch and swell of the veins.

An opening has been made on an antimony-bearing quartz vein on the ridge west of Manila Creek, about half a mile south of the Sliscovich mine. A shallow shaft is now caved, and the ore is not seen in place. To judge by the material on the dump, the vein is probably not more than 8 inches thick.

A number of openings have been made on antimony veins by Henry Breen, who has staked six claims between Clear Creek and the divide between the right fork of Manila Creek and Hobson Creek. (See fig. 17.) Several trenches and pits on the east bank of Clear Creek expose antimony ore. These are sunk in chlorite schist at a limestone and schist contact. The limestone is bleached but not noticeably silicified. Details of the occurrence of the ore are obscured by wash in the trench. In one cut the mineralized rock is exposed for about 6 feet. The part seen is 2 feet thick; the base is concealed, being overlain by gravel. The bottom of the pit is about at the limestone contact. In the ore on the dump stibnite is associated with quartz-calcite gangue. The relations are not clear, owing to the decomposed nature of the material, but the occurrence is probably one of stibnite in quartz, which lies in the limestone at a schist contact. Some stibnite also occurs as veinlets cutting schist.

A dozen or more pits have been dug S. 70° E. of the Cold Creek locality and on the west slope of the ridge between Steep and Manila creeks. No ledge is exposed. The country rock is chlorite schist. Some ore on the dumps would seem to indicate a vein trending about N. 45° E. and possibly 2 feet wide. The ore consists of stibnite and quartz and is similar to the other antimony ore of the locality.

The Christophosen antimony property is at the head of Waterfall Creek, about 5 miles west of the Sliscovich mine. (See fig. 19.) The lode is in a schist country rock. Development work consists of two tunnels and several open cuts. The upper tunnel, now caved and inaccessible, is said to be 105 feet long; the lower tunnel is 270 feet long and driven N. 25° W. According to Mertie,[62]

> The tunnels are said to intersect a stockwork of iron-stained schist and quartz in which the stibnite occurs as lenticular masses. None of the antimony stringers are over 12 inches in thickness.
>
> In the open cuts it is apparent that a shear zone striking about N. 20° E. runs through the property. The attitude of the faults is about vertical. This zone is about 100 feet thick and is heavily iron-stained and mineralized by pyrite, pyrrhotite, stibnite, and gold.

Little is exposed in the one tunnel which is accessible. About 60 feet from the portal a quartz vein, apparently a lens, is intersected which strikes N. 50° E. and dips 80° S. It is followed for 12 feet along its strike and apparently stoped. No evidence of mineralization is seen. At 70 feet from the entry a 3-foot quartz vein strikes N. 70° W. and dips north. The tunnel is driven in graphitic schist and exposes little quartz, other than that mentioned. On the dump quartz of the later-vein type contains considerable pyrite.

A 2-foot vein of quartz containing a little stibnite is exposed by the open cuts. It strikes N. 60° E. and dips north but can be traced for only a short distance. Quartz containing some stibnite occurs on the dumps of several open cuts. The antimony mineral, here as elsewhere, is later than the quartz occurring as veins through it. Concentrations of well-crystallized stibnite show included and evidently contemporaneous crystals of clear quartz, some of which have good terminations. The mineralized schist of the shear zone is exposed in several open cuts. The rock is a graphitic quartz schist containing a little sericite. It is highly iron-stained. Very little

[62] Mertie, J. B., jr., Lode mining and prospecting on Seward Peninsula: U. S. Geol. Survey Bull. 662, p. 439, 1916.

quartz-vein material occurs through the mineralized shear zone. According to Mertie,[63]

About 2½ tons of high-grade stibnite has been mined at this property and sold. The stibnite assays over 58 per cent antimony and carries also some gold and silver. Assays of the crushed schist and quartz in the shear zone also show a little gold.

ZINC-LEAD DEPOSIT ON STEEP CREEK.

The Nelson zinc-lead prospect is on the south slope of Mount Distin, near the headwaters of Steep Creek, a tributary of Goldbottom Creek (fig. 17). The developments consist of a 40-foot tunnel, a 30-foot open cut, and several pits. At the time of visit the tunnel was partly filled with water and inaccessible.

The country rock is limestone, with which is interbedded quartz-mica schist. Along a limestone and schist contact the limestone is bleached for a width of 30 feet. It strikes N. 15° W. and dips 18° W. Galena, sphalerite, and pyrite occur in the bleached limestone. At the mouth of the tunnel several stringers of sulphide occur parallel to the bedding of the limestone. The best exposure of the mineralized zone was seen in the open cut, where it is 6 feet wide. Almost every foot of face exposed, both laterally and vertically, shows sulphide, but the occurrence is very irregular and discontinuous. Veinlets of sulphide in the limestone parallel to its bedding constitute the usual mode of occurrence. One 2-inch veinlet of rather pure galena cuts the bedding and dips west at an angle of 35°. It is accompanied by gritty gouge, so badly decomposed that the relation of the sulphide to the gangue is not determinable. Viewed in the large the face of ore has a parallel structure, due to the arrangement of the veinlets. In detail the parallel zones are made up of smaller veinlets branching in all directions. The limestone here is not silicified. The sulphides occur as veinlets and replacement deposits in the limestone. Sphalerite is a common accessory mineral of the galena ores of Seward Peninsula but rarely occurs as the dominating sulphide. Mertie[64] has described such an occurrence in the headwater region of Penny River (fig. 19), as follows:

A zinc prospect consisting of two claims owned by G. Christophosen is on the ridge between Penny River and the head of Oregon Creek, at an elevation of 1,600 feet. The prospect lies N. 64° E. from the mouth of Nugget Creek.

The ore occurs in a small saddle on the ridge, in a narrow band of limestone country rock. A short distance away, on both sides of the saddle, the country rock is schist, and this rapid alternation of limestone and schist is a characteristic geologic feature in this vicinity. The strike of the country rock is N. 30° E. and the dip about 30° SW. There appears to be no well-defined vein but instead an iron-stained zone of mineralization, which trends approximately S. 8° E. The lode was located originally by float in the valley of Penny River. Development work consists mainly of a caved shallow shaft.

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[63] Mertie, J. B., Jr., op. cit., p. 439.

[64] Idem,. p. 447.

The ore is sphalerite, with a little pyrite, in a quartz gangue. Two kinds of quartz are present—the white, opaque variety and the clear, vitreous quartz. The latter appears to be either contemporaneous with the ore deposition or at least closely connected with it genetically. The ore is said to carry also some gold.

NOME REGION.

The richest placers developed in Seward Peninsula are those within a few miles of Nome, notably on Anvil, Dexter, and Glacier creeks. Gold placers have also been found at several localities in a belt some 15 miles wide and extending inland for some 20 miles. It is to be expected that where the richest placers have been found the greatest concentration of gold in bedrock would also occur. In spite of this apparently favorable condition and a large amount of prospecting, no commercial lode deposits have yet been developed in this region. It should be remembered, however, that mining costs, owing chiefly to the high price of fuel, mine timber, supplies, and transportation, are very high. A lode whose gold content was so low as to prohibit profitable exploitation under these conditions of high cost might be of commercial value if such conditions could be changed. Most of the prospecting has been done in search of gold, and both vein and shear-zone deposits have been explored. A number of deposits of antimony (stibnite) and several of tungsten (scheelite) have also received some attention.

The nature of the antimony mineralization has been described on page 225 and need not be mentioned further. Tungsten has been found in bedrock at Sophie Gulch, on Twin Mountain Creek,[65] in lodes on the north side of Glacier Creek, and on the divide between Glacier and Anvil creeks. In the tin deposits of the York district wolframite is associated with cassiterite. In the deposit cited above the tungsten mineral is scheelite. At Sophie Gulch it occurs as a contemporaneous constituent of the quartz-calcite veins and accompanying sulphides which have impregnated the schist adjacent to the veins. At Good Luck Gulch it is recognized microscopically, associated with pyrite, arsenopyrite, and quartz, replacing limestone. As it seems to be contemporaneous with both the later quartz veins and the arsenopyrite, more than one age of tungsten mineralization is certain. Scheelite is fairly common in the placers. It is known at Bluff and in the Council, Solomon, and Fairhaven districts and is probably widely distributed, perhaps as a minor constituent of the later quartz veins.

Quartz veins are very common in the Nome region. They occur as stringers and as massive veins as much as several feet in width. Free-milling gold is known to be present in veins as narrow as a quarter of an inch, but the gold content of all veins so far as known is uniformly

[65] Mertie, J. B., jr., op. cit., p. 437.

low. The feldspar type of vein is best known in this district, and the conspicuous veins are usually of that type. No great enrichment of the country rock seems to be assignable to the quartz veins. It seems more probable that enrichment has been effected by the formation of mineralized shear zones and that the gold has been derived from arsenopyrite, which is the usual metallic mineral of those zones. Two types of shear zone in which sulphides are abundant are known. In one the ore occurs in the schist; in the other it occurs along walls of the later quartz veins.

The relation of arsenopyrite to the later quartz veins is similar to that of stibnite. After the deposition of the veins movement reopened the fissures and shattered the veins, and solutions bearing arsenopyrite, gold, a little pyrite, and very little quartz were introduced along the reopened fissures, filled fractures in the veins, and impregnated the schist wall. Unaltered sulphides in these deposits are rarely exposed, and details of the associations can not be seen. The deposits appear at the surface as zones of decomposed schist, stained red by iron oxide. The intense mineralization as shown by the decomposition extended for only a few feet from the vein wall and diminished rapidly with increasing distance from the vein. Where the fresh sulphide can be seen it is chiefly arsenopyrite. The decomposed schist pans gold. Polished and thin sections have not shown free gold to be included in or associated with the sulphides, and the gold mineralization may in part be independent of the sulphides. Mertie [66] cites a mill run made on one of these deposits in which the sulphides are said to have assayed $48 to $65 a ton in gold.

The mineralization of the shear zone in schist is comparable to that of the schist adjacent to the later veins, which has just been described. Sulphides, chiefly arsenopyrite, impregnate the schist. Stringers of quartz cut the schist, usually not in great numbers, but at Sophie Gulch and on Glacier Creek zones of this type are exposed in which the veinlets form regular stockworks. The limits of the zones are not well defined, the sulphide mineralization having gradually diminished with increasing distance from the main surfaces of shear. The weathered outcrops are stained with iron oxide. According to report, the schists show a gold content on assay, and gold can be panned from the decomposed materials.

Many lode claims have been staked in the Nome region during the last 20 years, and on some of these claims considerable underground exploration has been done. Though a little gold ore has been mined and milled from some of these prospects, and a few tons of antimony has been produced, no commercial ore bodies have been blocked out. For the sake of elucidating the principles governing the distri-

[66] Mertie, J. B., jr., Lode mining and prospecting on Seward Peninsula: U. S. Geol. Survey Bull. 662, p. 432, 1916.

bution and mode of occurrence of gold in the bedrock, the principal prospects will be described. At the time of the writer's visit to this field in 1920 many of the old workings were caved and inaccessible. Fortunately, some record of the lodes is available, through the reports of Mertie [67] and Chapin,[68] who examined the region in 1913 and 1914. In the following descriptions extensive use will be made of these reports. The locations of the prospects here to be described, which lie close to Nome, are given on the accompanying maps (figs. 18 and 19).

Attempt to find a gold-bearing calcite lode is shown by some openings made by M. Charles at the head of Cooper Gulch, about half a mile east of Anvil Mountain. Here there are some small

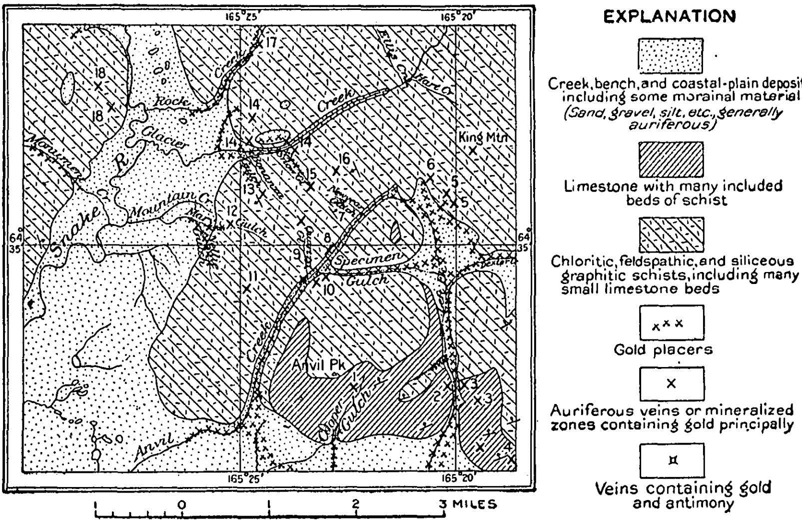

FIGURE 18.—Geologic sketch map of Anvil Creek and vicinity, 4 miles north of Nome.

reticulated veins of calcite which strike N. 30° E. Nothing encouraging the hope of finding a valuable lode was seen at this locality. The calcite veins and stringers carry some quartz and are iron-stained, showing the presence of a sulphide.

It is important to note the relation between the arsenopyrite deposits and some of the more productive placers of the peninsula as observed in the lodes at Bluff, at Koyana Creek, and on West Creek in the Solomon region (pp. 186, 198). The arsenopyrite-bearing rock is perhaps the most conspicuous type of mineralized rock in the Nome region, where it is known to occur on Goldbottom Creek, Good Luck Gulch, Boulder Creek, Gold Hill, Rock Creek, Sophie Gulch, Snow Gulch, Glacier Creek, Mountain Creek, New

[67] Mertie, J. B., jr., Lode and placer mining on Seward Peninsula: U. S. Geol. Survey Bull. 662, pp. 425–440, 1917.

[68] Chapin, Theodore, Lode developments on Seward Peninsula: U. S. Geol. Survey Bull. 592, pp. 397–407, 1914.

Years Gulch, and Anvil Creek and is suspected of being the source of the iron-stained schist of Dexter and Dry creeks. The known distribution of arsenopyrite in the Nome region as the principal sulphide mineral of the later quartz veins and of the shear zones suggests that it may be the same mineralization which has locally enriched the bedrock in this area and from which much of the gold of the rich placers has been derived. For many years prospectors have postulated a mother lode that supplied the gold for the rich placers of the Snake River drainage basin and the beach deposits. It is improbable that any one continuous lode exists. Relative enrichments such as are cited here would be sufficient to effect a tremendous concentration in the stream gravels if such enrichments were sufficiently numerous. The exposure of deposits of the shear-zone type in a country where the rock is concealed by moss, talus, and gravels is purely fortuitous or the result of mining operations. It is not improbable that such deposits are much more numerous than can be demonstrated. Shear zones comparable to those exposed in the Nome region are not known to the writer to occur elsewhere in the peninsula, but they are probably present. It would be natural to expect to find them developed in areas which have suffered the greatest deformation. The Nome and the Solomon areas probably fill this requirement. In the Ophir Creek region shear zones of this type were not recognized, nor was arsenopyrite seen. A different set of conditions, which are discussed elsewhere (p. 207), are believed to have effected the enrichment in that region.

Some work has been done on what is called the Rex lode, on the west slope of the Dry Creek valley. At an elevation of 550 feet a tunnel is driven 25 feet along a fault in limestone. The fault strikes N. 18° W. and dips 65° N., and the limestone strikes N. 40° E. and dips 10° N. A slightly iron-stained calcite vein, 1 foot or less in width, lies along the fault. The owner claims an assay of $3 to $5 in gold to the ton on this material. Another 25-foot tunnel 50 feet lower exposes the same vein. About 200 feet south of this second tunnel three tunnels have been driven on different veins and are now caved. One was 180 feet long. At an elevation of 480 feet a tunnel is now being driven N. 70° W. along an 8-inch vein of calcite. Here only calcite has been seen, and no quartz or sulphide minerals were observed.

A number of claims are staked on the Red lode, along the valley of Dry Creek, between elevations of 400 and 500 feet. East of the road just below East Gulch a pit exposes iron-stained schist similar to that observed on Dexter Creek. Both limestone and schist occur on the dump, and the hematitic material is probably related to the contact. A shaft 40 feet above the pit just mentioned is now caved. Limestone and quartz-chlorite schist but practically no quartz occur on the dump. On the east side of Dry Creek, at an elevation of 500 feet, a 25-foot tunnel, now caved, and a 30-foot trench 50 feet above it have been opened on a fault zone in limestone. The fault zone strikes N. 40° W. and can be traced on the hillside. The limestone along the fault is brecciated and stained by hematite and limonite, which are accompanied by considerable calcite. No sulphides were seen. The oxide mineralization here probably resulted from ground waters circulating along this shattered zone and is illustrative of what may be the conditions giving rise to the iron ores of the Cub Bear mine on Cripple River.

An open cut at an elevation of about 770 feet on the east side of Dry Creek exposes iron-stained limestone. The cut is now caved, but some greenstone containing pyrite is on the dump. The sulphide content of this rock may be the source of the iron stain in the limestone at this locality.

At the head of Newton Gulch A. Homberger has made a dozen or more openings in limestone and schist. Veinlets of quartz in the schist and a little pyrite form the only evidence of mineralization seen. No defined lode has been followed, but an average value of $5 in gold to the ton is claimed by Mr. Homberger as the result of composite sampling.

Arthur Hines and Charles McLaughlin have located five claims covering most of King Mountain and five claims on the north slope of Dexter Creek, between Deer and Grouse gulches. On Dexter Creek six shafts, five 20 feet and one 56 feet deep, were sunk but are now caved. They were sunk in limestone and decomposed, highly iron-stained schist. The country rock here is alternating schist and limestone. The schist where exposed is decomposed almost to soil and stained yellow. Little quartz is seen, and the decomposed material is said not to pan a color, but to assay $3 to $24 a ton in gold. The owners also claim that it contains platinum. Platinum in rock of this type would be entirely exceptional, and its presence or absence should be determined by a competent chemist.

South of these claims, at the mouth of Grouse Gulch, there is an old tunnel at creek level, said to have been 400 feet long and to have cut decomposed schist that showed an average of $11.80 a ton in gold for 150 assays. This schist is about half calcite and half quartz, with a very little sericite.

The bedrock of Dexter Creek is alternating limestone and schist. Very little quartz is seen, but the thin schist zones are highly mineralized and much decomposed. On Grass Gulch and Left Fork the rock is chiefly limestone with a little interbedded schist and almost no quartz. The limestone is bleached white at certain horizons, chiefly at schist contacts. Miners working here say that the richest placer ground is found on the bleached limestone.

Bursick & Kern have made 8 or 10 openings at the base of King Mountain on the south and southwest sides. All are in schist and expose very little quartz. No evidence of mineralization was observed. A 20-foot tunnel in schist exposes a few inches of quartz but no trace of mineralization. At an elevation of 640 feet Bursick & Kern have a cut 30 by 50 feet in white limestone. The adjacent schist is well mineralized. The limestone resembles the bleached limestone that accompanies the mineralized rock elsewhere. The bed is 4 feet thick but is neither silicified nor mineralized. On Nekula Gulch, a quarter of a mile to the southwest, is the Caribou Bill claim, one of the richest placers mined in the district.[69]

New Years Gulch, a tributary to Anvil Creek, is cut through a zone of mineralized schist and quartz-feldspar veins similar to the zones exposed on Glacier and Rock creeks. The zone is 25 feet wide and strikes N. 40° W. (?). The iron-stained schist is said to pan gold. The vein material is reported to carry arsenopyrite and pyrite, but none was seen by the writer. An assay made for the Survey on this oxidized schist did not show any gold.

At the Hendrickson prospect, on the north side of Anvil Creek between New Years and Specimen gulches, a 150-foot adit exposes a little quartz, limestone, and schist. The limestone is highly mineralized. Pyrite and arsenopyrite occur abundantly in small crystals in a slightly schistose type of limestone, and pyrite occurs also in a nonschistose phase. The quartz shows some arsenopyrite mineralization. According to Mertie,[70] the adit is reported to crosscut a belt of mineralized country rock for 120 feet, and within this belt lies a rich zone 15 feet wide, which assayed $11 to $12 a ton in gold. A shaft on the opposite side of the creek is filled with water.

On the east bank of Anvil Creek just below New Years Gulch hydraulic work exposes much jointed schist that is well mineralized and on weathering is discolored. In some places the discoloration is more intense than in others and might well represent higher concentration of sulphides, of which New Years Gulch is an extreme example. Quartz veinlets occur throughout the schist.

Some of the gold from the hydraulic bench on Anvil Creek just above Specimen Gulch is attached to quartz, some is clean, and one nugget showed only hematite in the crevices. All the nuggets are angular and probably local. The attached material suggests that the gold may be derived in part from the quartz stringers and in part from the sulphides.

On the north bank of Anvil Creek, opposite the mouth of Specimen Gulch, a tunnel 70 feet long has been driven in graphitic schist. The

[69] Collier, A. J., Gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, p. 200, 1908.

[70] Mertie, J. B., jr., op. cit., p. 431.

opening was made by J. C. Widstedt in 1899, and several tons of antimony was mined. The stibnite occurred in kidneys in the schist but not in large quantities. The schist in the vicinity of the stibnite kidneys is well mineralized by pyrite and arsenopyrite. Samples of the ore show coarsely crystalline stibnite and a little pyrite. It is said to have assayed $72 a ton in gold, $28 in silver, and some copper. Little can be seen in the tunnel, because of the sediment covering the walls.

On the west bank of Quartz Gulch, about halfway up the gulch, a shaft was sunk by Mr. Widstedt on an antimony-bearing quartz vein. The shaft is now full of water. The material on the dump consists of quartz, schist, and stibnite. The stibnite is finely crystalline and is associated with pyrite and a little arsenopyrite. In the quartz rock stibnite occurs in veinlets. Where stibnite predominates the relations of the quartz are not clear.

On the hillside northwest of this locality is another shaft now caved, out of which antimony is said to have been mined; only schist shows on the dump. On the east side of Quartz Gulch a small open cut exposes several parallel quartz stringers in iron-stained schist. The decomposed zone is 12 feet wide. Finely crystalline stibnite occurs in tiny veinlets in the quartz.

On the west side of Anvil Creek opposite the mouth of Specimen Gulch an open cut exposes a shear zone in schist. The schist is about half calcite and half quartz, with much graphite and a little muscovite. It is badly crumpled and iron stained. Numerous indistinct quartz veinlets cut the schist. Pyrite was the only fresh sulphide seen. Beginning 100 feet south of this exposure and continuing for several hundred feet a series of these sheared and iron-stained zones in schist are exposed by a cut made in building a road along the side hill. The occurrence is similar to that of the Boulder lode and other sheared zones which are known to pan gold and is probably representative of a type of sulphide mineralization common in the Nome district but not generally exposed. On the west side of Anvil Creek below Quartz Gulch several tunnels have been driven but are now caved and inaccessible. No ore was seen on the dumps. One of these tunnels was evidently driven on a limestone and schist contact. Quartz-calcite veinlets occur in both limestone and schist, and sulphides are prominent in both. At the mouth of Quartz Gulch on the Scotia claim a 10-foot tunnel exposes an 8-inch quartz-calcite vein, cutting schist. Both schist and quartz contain pyrite and arsenopyrite.

On the east bank of Anvil Creek a quarter of a mile below Specimen Gulch two shafts have been sunk by Charles Olsen on antimony-gold-quartz veins. One, 54 feet deep, is now caved; the other, 100 feet deep, is full of water. The 54-foot shaft, according to Mr. Olsen, was sunk on a 4-foot vein of quartz that strikes a little west of north and carried only a little gold. At a depth of 49 feet stibnite was encountered which continued to 54 feet, where the shaft was abandoned. The stibnite portion of the vein was more than 5 feet wide. The 100-foot shaft is 100 feet west of the 54-foot shaft. It encountered stibnite at 60 feet, which continued on the hanging wall to 100 feet, and at that depth the shaft was abandoned because of water. These veins dipped west and had 10 feet of talc schist on the hanging wall. The ore occurring on the dump is very finely crystalline stibnite with some pyrite and quartz through it. It is said to have assayed $21 to the ton in gold, $2.05 in silver, and some copper.

On the ridge between Anvil Creek and Snake River, southwest of Quartz Gulch, at an elevation of 650 feet, a big ledge of white, opaque (bull) quartz has been exposed by Peterson & Lamoreaux in an open cut and short tunnel. This body of quartz is 8 feet or more thick, strikes S. 45° W., and dips about 45° NW. It is heavily iron stained. The vein is not clean cut but shows stringers going off into the black schist country rock. Strongly developed fractures striking N. 35° W. are present in the quartz, as well as other irregular fractures and faults. This quartz has the appearance of having suffered considerable metamorphism and is probably an old quartz vein formed prior to the gold mineralization of the region. It is reported that galena was found disseminated in some of this quartz. A near-by shaft, about 40 feet deep, is filled with water.[71]

The Eureka and Borasco claims, usually known as the Jorgensen property, lie on Mary Gulch, a tributary of Mountain Creek. Here several openings have been made on quartz veins in mineralized mica schist and marmarized limestone. Oligoclase feldspar is prominent in some of the vein rock. Pyrite, arsenopyrite, and galena occur in veins cutting the quartz, and Mertie [72] reports scheelite from the same locality. The galena occurs in veinlets in the quartz but was not seen in association with the other sulphide and may represent a different period of mineralization. Scheelite may belong to either the quartz or the sulphide period of mineralization. The schist is highly mineralized with arsenopyrite and pyrite. The sulphides are concentrated along the vein, and in the weathered outcrop the schist adjacent to the vein is altered to hematitic material. This intensely iron-stained zone may extend a foot or more from the vein. It is reported that gold can be panned from this rock and that the vein carries gold. Shearing along the vein is apparent. The order of mineralization would seem to be as follows: Quartz, probably carrying a little gold and scheelite, was introduced first. Later movement, in part at least along the vein, reopened the fissure and shattered the quartz. Contemporaneous with or later than this movement sulphides carrying gold filled fissures in the vein and impregnated the

[71] Mertie, J. B., jr., op. cit., p. 432.
[72] Idem, p. 435.

schist wall rock. The gold content of this and of most of the quartz-feldspar veins of the area about which anything could be learned seems to occur chiefly in the sulphides.

About 200 feet above the forks of the creek a cut exposes quartz in limestone. The habit of the quartz occurring in the two formations is well contrasted. In the schist the veins are extremely irregular in the strike and dip and are subject to rapid pinching and swelling. In the limestone the veins are, as a rule, more clean cut but in places subject to irregularities. At this locality the quartz has followed in general the bedding of the limestone, but in two places it cuts the bedding and fills irregular openings. The quartz in the limestone shows some galena but seems to be less well mineralized than that exposed in the schist.

The Golden Eagle and Gold Bug claims of the West group are near the head of Bonanza Gulch, half a mile south of Glacier Creek, near the top of the divide between Anvil Creek and Nome River. Here a 120-foot adit has been driven on a vein of the quartz-feldspar type. It shows a little pyrite and arsenopyrite. The country rock is quartz-mica-chlorite schist and where exposed, adjacent to the vein, is intensely iron stained. This soft hematitic material is said to pan gold. The width of the mineralized schist zone is not determinable. It strikes about N. 70° E. The face of the drift exposes a nearly vertical 8-inch vein in a zone of soft, highly altered schist. The exposures do not show the structural features.

About 200 yards north of the west end of Hot Air bench, between Glacier and Rock creeks, a trench exposes a quartz-feldspar vein in which sulphides are abundant. Arsenopyrite and pyrite occur in veinlets that cut the feldspar and quartz. There is a noticeable association of the sulphides with the feldspar of the vein. The relations of the vein to the bedrock could not be determined.

On the south side of Glacier Creek above Snow Gulch several short tunnels are driven on quartz-feldspar veins. In one tunnel 100 yards above the gulch the vein exposed is 1½ feet thick. Arsenopyrite and pyrite occur in veinlets through the quartz and feldspar of the vein.

On the north bank of Glacier Creek, opposite the mouth of Snow Gulch, a tunnel driven 20 feet in schist exposes a 1-foot quartz-feldspar vein. The country rock, quartz-chlorite schist, strikes N. 60° W. and dips 20° N. The vein strikes east and dips south at an angle ranging from practically nothing to 45°. The schist is highly folded and irregular. The vein pinches and swells from 3 inches to 1 foot within the 6 feet of length exposed. An 8-inch lens of quartz is exposed above the vein but extends for only 2 feet. A 1-inch stringer dips north and merges with the vein. The quartz shows little or no mineralization, but the schist adjacent to it is well mineralized with arsenopyrite and pyrite.

A zone of mineralized schist impregnated by quartz is exposed in a small gully on the south bank of Glacier Creek just above the mouth of Snow Gulch. The occurrence is similar to that of Sophie Gulch. The zone appears to strike N. 30° E. Its width is not determinable. The schist has been literally shattered, and the fractures strike and dip in all directions. The schist included between veinlets is commonly curled and contorted along what probably are the surfaces of greatest movement. The veins are of the quartz-feldspar variety and from 1 to 3 inches in width. They are extremely irregular, pinching and swelling, forming lenses and blowouts, and ending as abruptly as they begin. They are all contemporaneous, branching and anastomosing and conforming with the fractures in the schist. The fissures filled are clean cut, and the vein walls are well defined. Between the veins and especially adjacent to them the schist is intensely iron stained. Only extremely decomposed material can be seen, so that the nature of the sulphide mineralization by which it was formed is not determinable. It is probably another exposure of that type of rock containing disseminated sulphides, which in places is known to carry gold and which may be very common, as the softness of the material would permit its exposure only under exceptional conditions. Both moss and talus would effectually conceal it.

The quartz veins are probably later than any considerable movement along the intruded zone, as no offsetting was observed. The sulphide mineralization of the schist was, at least in part, later than the introduction of the quartz, as arsenopyrite, the most abundant sulphide of these zones, occurs as veins in the quartz. How far the sulphide mineralization may have extended from the vein has not been determined, but to judge from the intensity of the decomposition colors it was largely concentrated within a few inches of the vein. This criterion is fairly reliable, as water circulation is not confined to the vein fissures, and the wall rock is cut in great detail by incipient fractures and is decidedly porous rather than dense, even in its most unaltered parts.

The localization of the schist mineralization largely along the fissures filled by quartz indicates the same control for the sulphide mineralizing solution as for the quartz. The old avenues of entrance were open, whether due to incomplete filling of the fissures by quartz or to later shattering that affected the vein walls. Free gold can be panned from many of these zones of decomposed schist. The quartz-feldspar veins are known to carry gold. Whether the gold is the product of a separate mineralization or related to the sulphide mineralization is not definitely known. According to Chapin,[73] the sulphides at the New Era tunnel do not pan free gold. The decomposed schists carrying the same sulphides in many places pan gold. At Bluff (p. 186) the ore is similar to that which is in part free milling and in part base.

At creek level, just west of Hot Air bench, on the north bank of Glacier Creek, two 30-foot open cuts and a 15-foot adit expose a vein of the quartz-feldspar type. The country rock is chlorite schist, which strikes east and dips 40° S. The vein is 8 inches thick and conforms in general with the irregular strike and dip of the schist. A fault in the schist at the tunnel face strikes N. 70° W. and dips 45° N. The vein has been terminated by the fault gouge on the west side of the drift and cuts the fault surface on the east side of the drift. It is almost certain from observations made on this vein that it is later than any period of serious deformation of the schist. It is shattered but not displaced. No sulphide mineralization of the vein was observed.

The Hot Air bench, on the north bank of Glacier Creek, was a large producer of placer gold. The bedrock is schist, and quartz is not plentiful. The schist is mineralized, but the shear zones observed in the bedrock of Rock and Anvil creeks are not seen here. It hardly seems possible that this gold could have been of local derivation. Microscopically the schist proves to be a quartz-albite variety in which chlorite is the most abundant micaceous mineral and muscovite is prominent. Sillimanite and titanite occur as accessories, and arsenopyrite seems to be the sulphide.

The New Era tunnel, on the west side of Snow Gulch, near its head, is now caved and inaccessible. The country rock of Snow Gulch is a succession of limestones and schists, and the tunnel is driven along one of the schist zones. Quartz, limestone, and calcareous schist on the dump are not representative of the mineralization, which is described by Chapin[74] as follows:

> The lode, as judged by specimens from the dump, is composed of stringers of quartz with much included schist, both quartz and schist containing considerable pyrite and arsenopyrite. The arsenopyrite occurs as small irregular bunches and as isolated crystals in both vein matter and schist and appears to be contemporaneous with the quartz. Some of the pyrite may perhaps have the same relation, but most of it is of later origin than the arsenopyrite and fills fractures which penetrate that mineral. A small amount of albite occurs with the quartz.
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> *   *   *   *   *   *   *
>
> No visible gold could be detected in any of the samples taken from this tunnel, nor can free gold be obtained on crushing the ore. The gold is contained in the sulphide and extends into the wall rock for a considerable distance.

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[73] Chapin, Theodore, Lode developments on Seward Peninsula: U. S. Geol. Survey Bull. 592, p. 400, 1914.

[74] Idem, p. 400.

West of Snow Gulch, at an elevation of about 450 feet, a trench 50 feet long and 12 feet deep at the face exposes a quartz-calcite vein in limestone. A 12-foot shaft and a 20-foot shaft on the strike of the trench expose the ledge for 100 feet to the southwest. The vein is 2 or 3 feet thick, strikes N. 20° E., and dips 15°–30° W. It conforms in general with the bedding of the limestone. A very little sulphide was seen in both limestone and quartz. Continuing along the direction of these openings, in a line N. 25° E., twenty or more pits have been sunk in quartz-muscovite schist. A little quartz, about equivalent to the quartz occurring in the schist anywhere, is on the dump at each opening, but no ledge is exposed. The pits extend for half a mile or more.

On one of the Big Four claims, on the east side of Snow Gulch above the Miocene Ditch tunnel, a 20-foot shaft and several open cuts have exposed a quartz vein system in limestone. The veins are of the quartz-calcite type, are of open texture, and contain a little sulphide. Free gold was observed in one vein at the contact of the vein and the limestone. In the shaft the veins occur dominantly with the bedding of the limestone but are also transverse to it. They appear to be fairly continuous and not to exceed a few inches in width. The limestone is underlain by schist, and several openings are made in the contact. The schist is highly mineralized.

Where the Government road crosses Rock Creek there is an outcrop of limestone which shows considerable sulphide mineralization. The mineralized limestone is dark blue to black, much contorted, slickensided on some surfaces, and cut by small veinlets of quartz. The microscope shows that it is partly replaced by quartz, being about half quartz and half calcite. The only sulphide observed is pyrite.

The folding in the limestone and schist is exposed on the creek bank. Along the crest of an anticline, where the limestone is in contact with schist, both rocks are unusually well mineralized. The schist resembles that of the Boulder and California lodes, being highly iron stained. No well-defined quartz veinlets occur in the mineralized rock, and apparently the mineralizing solutions contained little or no silica. Here, as at Good Luck Gulch, however, the sulphide accompanies the quartz in replacing limestone. The crest of a fold is here seen to have afforded an opening favorable to the introduction of the mineralizing solutions.

On the north bank of Rock Creek, 200 yards northwest of the road crossing, a caved 10-foot shaft exposes a 2-foot vein of the quartz-feldspar type. The vein strikes N. 30° W. and dips 90°. Several openings south of the creek are along the strike of this vein and possibly on it.

On the south bank of Rock Creek, just below Sophie Gulch, two tunnels, a shaft, and an open cut have been made on a quartz-feldspar vein. The tunnels are driven S. 75° E. and S. 25° E. about 100 feet apart, and the shaft is probably sunk at their intersection. Both tunnels are caved, and the shaft is filled with water. The vein strikes N. 65° E. and dips 50° S. It is partly exposed by a cut and appears to be 3 or 4 feet thick. The feldspar of the vein is albite. It also contains a little pyrite, arsenopyrite, and ilmenite. The country rock is quartz-chlorite schist, which is iron stained at the surface. Material on the dump of the shaft contains fresh sulphides, the ilmenite occurring on fractured surfaces in the quartz.

This is the property referred to by Mertie as the Stipec and Kotovic property. He says:[75]

> The tunnel cuts a 12-foot vein of white opaque quartz which is greatly shattered and iron stained. A mill run on this material has shown it to contain 250 pounds of concentrates to the ton of rock milled and $6.25 a ton in free gold. The concentrates, which are chiefly arsenopyrite and pyrite, are said to assay from $48 to $65 a ton in gold. It is said by the owners that the schist in the mineralized zone carries more gold than the mineralized quartz.

In a hydraulic cut (Reinisch pit) on the north bench of Rock Creek opposite Sophie Gulch free gold was observed in a quartz stringer cutting black schist made up essentially of quartz, muscovite, and carbon. The stringer consists of white, vitreous quartz, about half an inch wide, which abounds in openings. In places the fissure is clearly incompletely filled, well-terminated crystals projecting from one wall, while no quartz occurs on the wall opposite. The gold seems to occur on the crystalline quartz and to be later than the quartz, but the evidence is too meager to warrant a positive statement of this relation. The miners report that gold usually occurs between the quartz and the wall rock.

Mertie[76] has described the occurrence of scheelite on Sophie Gulch as follows:

> The property known as the Sophie lode, on Sophie Gulch, a tributary of Rock Creek, consists of one patented placer claim and two lode claims. Residually weathered tungsten ore was mined here by placer operations in 1916. * * * The results of microscopic work on this lode will be included in a later report.
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> The country rock at this place is an iron-stained, thin-cleaving, foliated mica schist. the cleavage of which, measured at one place in the pit, strikes north and dips 23° E, It shows also a vertical jointing trending N. 35° W. Many well-developed fissures are present, striking N. 45° E. and nearly vertical or dipping steeply to the northwest. These are filled with iron-stained shattered quartz. Such veins range in thickness from a fraction of an inch to a foot or more. There is great irregularity in these quartz stringers, most of them thickening in places and thinning in others; also stringers run out into the country rock. Iron-stained fault planes striking N. 18° W. and dipping 54° E. cut both the country rock and the quartz stringers, and along these there is little or no quartz but considerable iron-stained gouge material.

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[75] Mertie, J. B., jr., Lode and placer mining on Seward Peninsula, U. S. Geol. Survey Bull. 662, p. 433, 1917.

[76] Idem, p. 436.

The scheelite occurs for the most part along the sides of quartz stringers and disseminated in the mica schist. Locally the scheelite is present in the quartz. It is reported that gold occurs in the iron-stained schist outside of the zone of scheelite mineralization, but no gold is reported to have been found in the scheelite-bearing rock. Besides scheelite, however, arsenopyrite, pyrite, and galena are found in the form of later veinlets definitely cutting the quartz.

It is said by the owners that the belt of scheelite mineralization is about 50 feet wide and has so far been traced about 500 feet in each direction from the open cut. The trend of this zone appears to be that of the iron-stained quartz veins and stringers—that is, about N. 45° E. The northwest side of the lode is reported to carry more scheelite than the other side. Two shafts—one 32 feet deep, northeast of the open cut, and the other 28 feet deep, southwest of the cut—have been driven to ascertain the value of the ore along the lode. It is said that these shafts show a higher content of scheelite in depth than at the surface.

The writer can supplement the above description by his own observations. The veins are all contemporaneous, cut the schist in all directions, and form complex patterns on the walls of the cut. They are of the quartz-feldspar and quartz-calcite types, are badly shattered, and crumble under the pick. Adjacent to the quartz and extending several inches or a foot from the vein the schist is intensely iron-stained, having the appearance of hematite. Where the veins are close together the entire body of intervening schist may be so altered. Arsenopyrite, galena, and pyrite occur in veinlets through the quartz. Arsenopyrite is also seen in the wall rock of the vein and is probably the mineral from which the hematite is derived. The iron-stained and highly mineralized schist is said to carry gold. A specimen of scheelite-bearing quartz vein material from this locality showed the scheelite to be yellowish brown and the quartz clear and colorless. White calcite is a prominent constituent of the vein rock.

At the mouth of Sophie Gulch a tunnel has been driven on a quartz-feldspar vein in a zone of mineralized and highly iron-stained schist. The tunnel is caved and inaccessible. Vein material on the dump contains arsenopyrite.

Just east of the mouth of Sophie Gulch a hydraulic pit on the south side of Rock Creek exposes highly mineralized chlorite schist that strikes N. 40° E. and dips 20° E. The schist is cut by 23 quartz veins from 1 to 8 inches wide in an exposed width of 28 feet. The veins are roughly parallel and alined about with the strike of the schist. Arsenopyrite, galena, and stibnite were observed in the veins, which are of the open-textured quartz-feldspar type. The schist is mineralized, and hematite occurs along the vein walls. Concentrates from the sluice boxes at this pit are chiefly scheelite, quartz, and schist. Placer gold with very delicate structure and attached to quartz also occurs and is undoubtedly derived from a local bedrock source.

Half a mile above Sophie Gulch, on the south bank of Rock Creek, a tunnel is driven S. 55° E. in chlorite schist. The working is inaccessible. Ore on the dump is quartz-feldspar vein material containing arsenopyrite and pyrite. The schist adjacent to the quartz is impregnated with fresh sulphides and is in all probability the equivalent of the hematitic schist which is of common occurrence on Rock Creek and which pans gold in many localities. The arsenopyrite mineralization seems to have been later than the vein and probably followed the same fissure as the quartz.

Two openings have been made on quartz veins on Gold Hill, in the Snake River valley between Monument and Thompson creeks. At an elevation of about 150 feet, opposite the mouth of Rock Creek, an open cut exposes a vein of the quartz-feldspar type. No sulphides were observed in the quartz, but it is said to assay $3.50 to the ton in gold. The country rock is much contorted quartz-chlorite schist, which in the vicinity of the vein is highly iron-stained and is said to pan free gold. The vein is about 2 feet thick, strikes N. 25° W., and dips south. The attitude of the vein is conformable with the structure of the schist, being very irregular and changing from horizontal to vertical where exposed. Small quartz veinlets ramify through the decomposed schist in the vicinity of the vein. Near the top of the hill a trench exposes a similar vein in highly decomposed and iron-stained schist.

On the north bank of Albion Creek, tributary to Rock Creek, a shaft said to be 50 feet deep has been sunk on a quartz vein. The shaft is now partly filled with water. No vein is in sight, and only a little quartz and some slightly mineralized schist appear on the dump. The vein is said to have given assays of $120 a ton in gold but to have pinched out. No work has been done on the property for years. The country rock is chlorite schist. Quartz stringers are abundant in the schist at this locality.

Two openings have been made in schist and in vein quartz at the mouth of Good Luck Gulch, a tributary of Snake River from the east 3 miles north of Rock Creek. The southerly opening consists of a 40-foot trench trending N. 75° W. The banks of the trench are caved, and no rock is exposed in place. The schist is highly iron-stained and decomposed. Some quartz vein material occurs on the dump, and several sacks of ore apparently from this working are stacked on the river bank near by. The material is highly mineralized. Pyrite and arsenopyrite occur in a gangue of quartz and calcite, through which muscovite in small flakes is scattered in considerable amount. Arsenopyrite is the more abundant of the sulphides. A single small crystal of scheelite is seen in thin section. In hand specimen the rock is blue and calcareous. It is probably a replaced limestone, but there is no field evidence to verify this conclusion.

Several pits along the strike of the lode expose no rock in place. Material on the dump includes iron-stained schist and a little banded quartz rock containing pyrite and similar in appearance to the copper ores of Copper Mountain (p. 217). The bedrock occurrence of this material can not be seen.

About 100 yards north of these pits a trench 30 feet long is driven N. 85° W. along the strike of a vein which dips 70° S. The vein is almost covered by débris. Where exposed it is 1 foot wide at the surface and 3 inches wide where it disappears in the trench floor. Material on the dump indicates that the vein may have had a thickness of 3 or 4 feet in one place. The vein is of the quartz-feldspar type and shows openings lined with quartz crystals. Pyrite and arsenopyrite occur through the quartz. The including rock is highly mineralized quartz-mica schist that strikes N. 75° W. and dips 25° N.

Many of the streams tributary to Nome River from the west between Alpha Creek on the south and Last Chance Creek on the north carry auriferous gravels, and these have locally yielded much placer gold. These creeks therefore apparently traverse a zone which is locally auriferous about 8 miles in length and 2 miles in maximum width. More accurate evidence of bedrock mineralization has been found at many localities in the form of auriferous zones and small quartz veins. Moffit [77] in 1906 noted the presence of mineralized bedrock in this zone as follows:

A large amount of highly mineralized quartz is present in schist exposures south of Good Luck Gulch. The quartz is much crushed and in general occurs as stringers, although at one place a mass 4 or 5 feet wide is exposed in a small outcrop. A prospect hole shows much rotten iron-stained quartz. The schist also is filled with iron oxide, in which some pyrite still remains. Panning shows the presence of gold.

Several quartz veins, the largest of which is about 5 inches thick, occur near the mouth of Boulder Creek. Assay values of $3 to $4 a ton in gold were obtained from samples taken here.

On Pioneer Gulch the best ground of the residual placers occurs just below a number of small quartz stringers cutting the schist bedrock. One of these stringers 3 inches thick showed considerable free gold. Similar occurrences are known in other parts of the region, but nowhere has the number or size of the mineralized veins been sufficiently great to constitute an ore body.

Moffit [78] noted the presence of scheelite and hematite pebbles associated with the placer gold of Bangor Creek, which contained fragments of scheelite weighing half a pound. The placers of Last Chance Creek, he states, carry scheelite, hematite, magnetite, and pyrite.

In 1907 Claus Rodine found a gold-bearing ledge on Twin Mountain Creek. Since then gold-bearing lodes have been found at a number of other localities in this belt. The general features of the bedrock geology are simple, for the belt is made up almost entirely of schist,

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[77] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, p. 131, 1913.

[78] Idem, p. 87.

which here and there includes some beds or lenses of limestone. There are, however, considerable local variations in the geology, for the schist includes feldspathic, micaceous, chloritic, and graphitic varieties. The schists in general trend north and are closely folded and much faulted. The evidence in hand goes to show that the mineralized zones are in general parallel to the schist, though there are some local variations from this strike.

Alpha Creek, the most southerly of the streams in this belt, has produced considerable placer gold. This gold is but little worn and probably of local bedrock derivation. The creek is cut in gravel, and the country rock is exposed only where a small area has been cleaned in mining. The bedrock exposed is chiefly quartz-mica schist and is well mineralized. Many quartz stringers cut the schist. The quartz is of a clear vitreous granular variety containing some fresh and considerable decomposed sulphide. A. C. Stewart is said to have had $12 assays on some of these stringers, but a composite sample of the quartz veinlets assayed for the Survey did not show any gold content. A little limestone and a little quartz from a larger vein than any seen occurs in the wash, but the gravel consists largely of the local schist and quartz stringer material. This occurrence would appear to be assignable to local quartz veins in schist bedrock, but the veinlets that would logically seem to be the source gave negative returns when assayed. Either the gold is not uniformly disseminated through the quartz or it is concentrated in certain veins. It is quite probable that the gold may have come from the mineralized schist and not from quartz veins.

There has been more prospecting of lodes on Boulder Creek and its tributary Twin Mountain Creek than in any other part of this belt. Here a large group of claims was located in 1915 by W. L. Cochrane and Claus Rodine, of the Dakota-Alaska Mining Co. This and other groups extend from Alpha Creek on the south across Sledge and Boulder creeks and up Twin Mountain Creek nearly to its head. Another group of lode claims covers much of the valley of Boulder Creek.

A vein of quartz has been opened on the north slope of Sledge Creek about 1½ miles above its mouth (fig. 19). This vein, as shown in a cut about 20 feet long, is about 2 feet wide, strikes N. 40° E., and dips 70° E. It is made up of quartz and orthoclase feldspar. Some masses of feldspar measuring several inches were seen in the vein. The quartz is iron-stained, but no sulphides were observed in it.

Mertie[79] has described the lodes of Boulder Creek as follows:

A number of lode claims on Boulder Creek owned by W. L. Cochrane and Claus Rodine are being prospected. The Boulder lode, embracing several of these claims,

[79] Op. cit., pp. 427–429.

is on the southwest side of Boulder Creek at an elevation of about 250 feet. Development work on this lode up to November, 1916, consisted of a tunnel driven 92 feet into the hillside on the southwest side of the creek. The direction of the tunnel, 60° W., is about the same as that of the cleavage in the schistose rock. The rock through which the tunnel is being driven is a much altered schist, heavily impregnated by iron-bearing solutions and cut by numerous veins and lenses of white, opaque quartz and also by thin stringers of limonitic material.

It is apparent that the gold in the tunnel has a genetic relation to the iron minerals, but it is not believed by the writer that the white, opaque quartz had any direct connection with the gold mineralization, for the quartz shows the effects of shattering and iron impregnation in a measure comparable with the schist itself and therefore was present prior to the mineralization. The presence of the white, opaque quartz is believed to be merely fortuitous, though it may have had an indirect influence on the mineralization by assisting mechanically or chemically in the precipitation from the mineralizing solutions.

The only quartz seen by the writer other than the white, opaque quartz was a veinlet of clear granular quartz, about three-eighths of an inch thick, near the face of the tunnel. Evidently the mineralization took place with very little deposition of silica by the auriferous solutions.

About 50 pounds of stibnite was taken from an open cut at the surface a short distance west of the tunnel. Scheelite in well-developed crystal outline has also been found in the white quartz in the tunnel. It is rather likely that the scheelite represents another stage in this mineralization, or possibly an entirely different period of mineralization.

At the time of the writer's visit to this lode the tunnel had been driven 85 feet, and although there was much evidence of mineralization in the iron-stained schist sulphides in any notable amount had not been found. Subsequently, in further driving of the tunnel, sulphide ore was encountered in the lode material. Specimens of the last material taken from the tunnel were sent to the writer by Mr. Rodine and prove to contain both pyrite and arsenopyrite.

The Boulder lode is similar in many respects to the California quartz lode on Goldbottom Creek—that is, it is a lode of the disseminated type—a mineralized body lying probably in a zone of shearing. Mr. Rodine says that the trend of the lode, or, in other words, of this zone of disturbance, is about N. 3° E. If this is the correct direction of the lode, it would appear that the tunnel has crosscut about 76 feet of the mineralized zone, and in striking the sulphide ore the tunnel is probably entering the higher-grade ore.

Assays have been made about every 10 feet in this tunnel, and these, known in a general way to the writer, are considered favorable in so large a body of mineralized rock. If the assays are reliable, there is here evidently a good-sized body of low-grade ore. Yet the owners should do a great deal more prospecting on the lode, particularly drill-hole prospecting, to determine its width and extension before making preparations for a milling plant.

On the northeast side of Boulder Creek another tunnel 35 feet long has been driven on the Dakota lode, which embraces 13 claims. The country rock here is limestone, with a minimum of iron staining and practically no sulphides. Veins of white, opaque quartz and of calcite are present, but there seems to be little indication of any intense mineralization.

Bedrock is uncovered in a pit in the creek bed on claim No. 1 below Discovery, Boulder Creek. The country rock is an iron-stained schist, the cleavage of which strikes N. 60° W. and dips 30° SW. A fault zone trending N. 30° W. and dipping southwest cuts through the schist at this locality. A vein of the white quartz near by strikes N. 60° E. and dips steeply northwest. The fault zone is greatly iron stained and cut by limonitic stringers. This material pans gold, and some very rich pieces of gold-bearing white quartz have been taken from this locality.

An open cut on the northeast side of Boulder Creek farther downstream has exposed a good-sized ledge of the white quartz. This is chiefly of interest on account of the presence of pyrite and pyrrhotite together in the quartz, the pyrrhotite being much less plentiful in the Nome district than pyrite or arsenopyrite.

When the writer examined this locality the mine workings were not accessible, but he was able to make more detailed observations on some of the bedrock geology than Mertie.

A 20-foot cut in the hillside near the mouth of Boulder Creek on the north bank exposes a quartz vein. The country rock is chlorite schist, striking N. 15° E. and dipping 15° E., which is highly contorted and shows considerable decomposed sulphide. The vein occurs as several stringers which in part cut across and in part conform with the schistosity. It swells to a foot in width and pinches to a few inches within a few feet. It is of the quartz-calcite type. No mineralization was observed.

On the north bank of Boulder Creek about 200 yards below the mouth of Twin Mountain Creek a 35-foot tunnel is driven in limestone. Several small stringers of quartz and calcite are intersected. Pyrite occurring in calcite is the only metallic mineral observed.

Near the mouth of Twin Mountain Creek and on the east bank two tunnels have been driven on veins of the quartz-calcite type. One is caved and inaccessible; the other, 40 feet long, is driven in chlorite schist and exposes a quartz-feldspar vein 15 feet from the portal. This vein swells from 1 inch to 1 foot in thickness and pinches to a stringer within 4 feet. Pyrite and a little arsenopyrite occur in veinlets through the quartz, and scheelite is said to be a constituent of the vein. The tunnel is driven S. 85° E. The schist strikes N. 5° E. and dips east. The vein in general conforms with the strike and dip of the schist.

The bedrock of Twin Mountain Creek is schist for several claims above the mouth. The gold it contains is hardly assignable to the influence of limestone, but rather to quartz veins, which are plentiful. Miners claim that the gold comes from an older and higher channel. The creek is incised in high terraces which merge with the terraces of Boulder Creek.

The Boulder lode is on the south side of Boulder Creek about a quarter of a mile above the mouth of Twin Mountain Creek. The workings consist of the tunnel described by Mertie and a shallow shaft. Both are now caved and inaccessible. The lode is evidently a shear zone in schist. The schist is highly stained with iron oxide, and some quartz occurs in stringers through it. To judge from the alinement of the workings and from traceable scars in the hills north of Boulder Creek valley, the strike of the lode is about north.

Limestone both underlies and overlies the schist zone of the lode, which is about 100 feet wide. The underlying limestone shows close folding both along its strike and along its dip, a feature which is well shown on the differentially weathered fracture surfaces of the beds. The stratigraphic position of the mineralized schist zone is shown by exposures along a ditch in the creek bank. West of the lode limestone immediately overlies it. The limestone strikes N. 10° E. and dips 20° W., thus conforming in general with the strike of the lode. Overlying this limestone, which is 50 feet or more thick, schist predominates in the section to the head of Boulder Creek. One considerable bed of limestone occurs about half a mile to the west, but it dips east and may be the same limestone which overlies the lode, duplicated by folding. To the east of the lode the series is predominantly limestone, with interbedded schist. The limestone occurs in thicknesses of 50 to 100 feet, and its structural relations are complex. East, west, and northeast dips are recorded within a few hundred feet. The included beds of schist are well mineralized.

Apparently the lode represents a zone of shearing in the schist at the contact of a zone which is predominantly limestone with a zone which is predominantly schist. The limestone near the lode is completely marmarized and shows intense deformation in detail and everywhere a complexity of structure. No doubt shearing occurred along all the schist zones in the limestone, for they are well mineralized, but the greatest adjustment occurred at the margin of the limestone mass, and this became the most favorable opening for later mineralizing solutions.

The lode rock is quartz-mica schist, in which chlorite and muscovite are abundant. Quartz is not present in any great amount. The material on the dump is of the later open-textured quartz-calcite vein type. Sulphides are abundant in the schist and occur also in the quartz and limestone and in calcite veins in the limestone. Pyrite is most common. Both pyrite and arsenopyrite occur as veinlets in the quartz. Mertie reports stibnite in the lode.

The lode in many respects is similar to that occurring on Goldbottom Creek. Two "runs of gold" are claimed for placers of Boulder Creek. Rough gold occurs below the point where the creek cuts the Boulder lode and is thought to be derived from the lode. The creek gold above the lode is fine and is assigned to the old stream gravels of the terraces that occur along the slopes.

The Lilly lode is on the saddle at the head of Twin Mountain Creek (fig. 19). Here a shallow trench at the limestone and schist contact exposes limestone cut by quartz veinlets and some iron-stained graphitic quartz schist. The limestone is somewhat silicified and shows decomposed pyrite in places, but no other sulphide was seen.

A few hundred feet west of this locality a 12-foot drift is run along a quartz vein in limestone. The limestone is an outlier on the schist and covers only an acre or so. No mineralized rock was seen in place, but a little mineralized quartz occurring in veinlets of ¼-inch size, closely spaced and parallel to the lamination of carbonaceous schist, contains pyrite, malachite, and probably chalcopyrite. The relations of these minerals to the country rock could not be determined.

Considerable placer gold has been mined on Pioneer Gulch, 2 miles north of Bangor Creek. Here the bedrock is not exposed, but Moffit has described the placers as being of residual origin. The alluvial gold is angular, and some of it is attached to quartz, indicating its source in the near-by bedrock. An old shaft on the creek bank is inaccessible, but to judge by the material on the dump it was opened on a quartz-calcite vein of the open-textured type, containing a little pyrite and arsenopyrite.

Last Chance Creek, where there has been considerable placer mining, is 2 miles northwest of Pioneer Gulch. Here Moffit noted the occurrence of scheelite. Near the mouth of Waterfall Creek, a tributary to Last Chance from the north, are exposed quartz veins which cut chloritic schist. The schist is highly folded, contorted, and fractured, and dips in general about 45° NE. Opaque quartz of the later-vein type containing a little pyrite occurs in veins from 1 inch to 1 foot wide along a shear zone in the schist. The zone strikes in general east and dips north. The quartz veins both follow and cut across the schistosity of the country rock. They are contemporaneous, as they do not offset or terminate one another but merge. This type of vein occurrence becomes prominent farther south in the Snake River valley. The Christophosen antimony lode, at the head of Waterfall Creek, has been described on page 231.

The California quartz lode is on Henry Gulch, a small tributary of Goldbottom Creek about half a mile from the Goldbottom-Mountain Creek divide. It is 20 miles north of Nome (fig. 19). The developments consist of a 70-foot shaft sunk on an incline of 60° and a 12-foot open cut in the creek bank. The shaft is said to have been sunk on the lode and to have left the lode at a depth of 33 feet. It was filled with water at the time of the writer's visit, and the lode was exposed only in the open cut. The property is equipped with a stamp mill having a theoretical capacity of 10 to 12 tons in 24 hours. Water power is supplied by a ditch 3 miles long, with intake on Fred Gulch. The mill equipment consists of a Blake Hercules jaw crusher, a battery of three 1,000-pound stamps, and a Pinder table. Most of the gold is recovered on the plates, the table having proved unsatisfactory, owing to sliming of the ore. No ore has been milled for several years, and the equipment is not in the best state of repair. Practically no work has been done here since Mertie's visit in 1916. The lode occurs along a shear zone in the Nome schist, about 300 feet from the limestone area of which Mount Distin is a part. Mertie [80] describes the lode as follows:

The lode matter consists of shattered quartz and country rock, which are heavily iron stained and mineralized. The ore body lies along a shear zone, which has a general strike of N. 15° W. The shearing seems to have taken place along a number of faults, with this general strike and with variable dips to the northeast, but to have been concentrated along the hanging-wall side of the shear zone. The hanging wall is therefore marked by a well-defined fault, with slickensided walls. Below the hanging wall, for about 4 feet, the lode matter is greatly crushed, iron stained, and mineralized, and it is from this part of the lode that the ore has so far been taken. The footwall is not well defined, the lode merging gradually into the country rock on that side.

The country rock in this vicinity is chlorite and sericite schist, with considerable graphitic slate and some thin bands of limestone. These rocks contain a system of old quartz veins, which are parallel to one another and lie conformably with the cleavage of the schist, striking N. 40° E. and dipping 50° SE. The shear zone, which strikes N. 15° W., cuts diagonally across the quartz veins, and the character of the lode matter is therefore variable. At one locality it may be entirely the red, iron-stained shattered schist; at another it may be dominantly the mineralized vein quartz. * * *

The lode system is crosscut by the creek and well exposed. The mineralizing solutions were effective for a considerable distance laterally, for the iron staining is plainly apparent for 300 feet upstream from the lode and for a considerable distance downstream. The owner says that this zone of shearing may be traced 1 mile to the northwest and 2 miles to the southeast.

Pyrite and arsenopyrite are the principal mineralizing agents, but here and there a little free gold may be seen. In this as well as in most other gold lodes in the Nome district very little quartz has been introduced with the mineralizing solutions. Stibnite is reported to be present in seams 2 inches or less in thickness, but these were not seen by the writer. Hydrous manganese oxide is present in the gouge. Molybdenum and tungsten also are reported from assays.

The 4 feet of ore along the hanging wall is said to have a value of about $50 a ton, as indicated by assays, but the owner has been able to obtain only from $8 to $10 a ton from the plates. It is therefore inferred that much of the gold is either mechanically intergrown with the sulphides, in particles of microscopic or submicroscopic size, or chemically combined with the sulphides.

Several quartz veins 1 to 3 feet wide that crop out on the north side of the creek appear to be on the strike of the lode and a part of it. On the north bank, 75 feet west of the veins, a highly mineralized schist crops out which has no counterpart on the south bank. It is said that the fault surface of the lode has been traced along a sinuous course to this outcrop. Microscopically the rock is found to be a carbonaceous quartz-muscovite schist, containing considerable chlorite and a little sillimanite, zircon, and tourmaline. Sulphides are abundant.

Gold is said to occur throughout the mineralized schist of the lode. The schist is essentially a graphitic quartz-mica schist. Both mus-

[80] Op. cit., pp. 426-427.

covite and biotite are present, the latter largely altered to chlorite. Pyrite and arsenopyrite are plentiful.

No quartz ore was seen in place, but a sample of the better grade of gold-bearing quartz taken from the shaft was given to the writer. Microscopically the rock is seen to contain some oligoclase feldspar, and it is probably related to the quartz-feldspar veins. It includes considerable schist and in places is essentially schist cut by quartz. Free gold can be seen in the quartz. Arsenopyrite and pyrite are abundant, and apparently contemporaneous with the quartz. Stringers of quartz that cut the schist are of the later vein type but were not found to contain feldspar.

About 1 mile below the California quartz lode mine, on the west bank of Goldbottom Creek, a 60-foot tunnel is driven in chlorite schist. A small outcrop of quartz occurs above the tunnel, and several stringers of vitreous quartz showing a little pyrite are cut by the tunnel. No definite lode is apparent.

Two small tunnels have been driven and a shallow shaft sunk near the head of Goldbottom Creek on the south bank just above the forks. All the workings are now caved, and neither the lode nor the inclosing rock can be seen, on account of the cover of moss and earth. Some graphite schist, vein quartz, and mineralized siliceous rock, probably a silicified limestone, lie on the dumps, also some limonitic gossan material. There is no evidence upon which to judge concerning the size of the vein or its occurrence. No work has been done here for years, but work is said to have been in progress for a considerable time.

The most conspicuous and plentiful material on the dumps is the silicified limestone, in which considerable sulphide occurs. The rock abounds in openings into which well-terminated quartz crystals project. The openings are in general parallel, fissure-like, and discontinuous. Many of them are filled with calcite. Pyrite seems to be the only sulphide. It occurs in small isolated crystals, in nests, and in roughly parallel streaks. The sulphide does not fill the openings but occurs through the quartz. The rock is noticeably banded, owing in part to the open texture and calcite filling and in part to the arrangement of the sulphides. The quartz vein material indicates a vein of the later type. Openings occur in it, but no sulphide was observed. The schist is of a graphitic quartz variety in which the graphite occurs in distinct flakes. No sulphide was observed in the schist.

Two prospects which are somewhat north of the Nome district proper are of interest and will be described. One of them is on Buffalo Creek, a headwater tributary of Nome River, and lies well within the Kigluaik Mountains. The other is in Slate Creek valley, about 15 miles to the east.

The Buffalo Creek lode is on the west slope of the valley about 1 mile from the mouth of the stream. It is a quartz vein about 2 feet wide, strikes N. 45° E., and dips south. The vein follows a shear zone in schist of the Kigluaik group and ranges in dip from 45° to horizontal. The footwall is much sheared, but the nearest determinable wall rock is biotite schist. The vein is iron-stained quartz but shows no mineralization. A tunnel is driven in the soft, decomposed schist footwall for 20 feet parallel to the ledge but does not cut it.

The deposit on Slate Creek, staked under the name "Osmun lode," is described by Chapin [81] as follows:

A prospect is being opened on Slate Creek, a small stream which flows into Kruzgamepa River from the south 4 miles east of Salmon Lake. The lode is a mineralized dike cutting greenstone. The rock is badly weathered, so that its original character is in doubt, but it appears to have been a fine-grained quartz-feldspar rock in which all the feldspar is now replaced by sericite and kaolin. The dike has been fractured and filled with ferruginous calcite that has partly replaced the included fragments and the walls. A later fracturing of the lode was healed by irregular veinlets composed of quartz and calcite deposited simultaneously. No assays of this lode were made, but small amounts of gold were obtained by crushing and panning the rock. The ledge, which is about 3 feet wide, strikes east and dips 70° N.

A short distance south of the open cut mentioned is an outcrop of rock which appears to be another dike about 10 feet thick and parallel to the one described. It is an even-textured rock of gray color and very fine grain and, like the other dike, was probably a quartz-feldspar intrusive. Quartz, the only original mineral now found in it, occurs with a finely granular mass of epidote. Traversing the rock in many directions are irregular veinlets composed mainly of a green silvery micaceous mineral which proves to be chlorite. With it are associated a number of other vein minerals—quartz, albite, calcite, epidote, and a colorless amphibole which is probably tremolite. This dike is not thought by the prospectors to be of economic value, and work has therefore been confined to the other lode.

The country rock is a fine-grained greenstone. It is evident that this was originally a basic igneous rock, but it has been entirely recrystallized. Green hornblende is the most conspicuous mineral, but considerable amounts of chlorite and epidote are present. Garnet and pyrite are abundant and may be readily seen in the hand specimen. Albite fills the interspaces and includes rutile and titanite and fragments of other minerals.

The Steiner lode is on the west side of Penny River about 4½ miles from the coast of Bering Sea, at an elevation of about 200 feet (fig. 19). Here a shaft has been sunk 105 feet and a drift run 220 feet N. 50° W. The shaft was started on a quartz-feldspar vein striking east, which is not now exposed. It is said to have been 5 to 10 feet wide and traceable for 1,000 feet on the surface. The quartz continued to a depth of 60 feet in the shaft and then dipped north. The shaft was continued 45 feet and a drift was run to intersect the vein but did not reach it. The quartz is said to have assayed $7 a ton in gold. The drift is run in quartz-mica schist and graphitic quartz schist.

[81] Op. cit., p. 405.

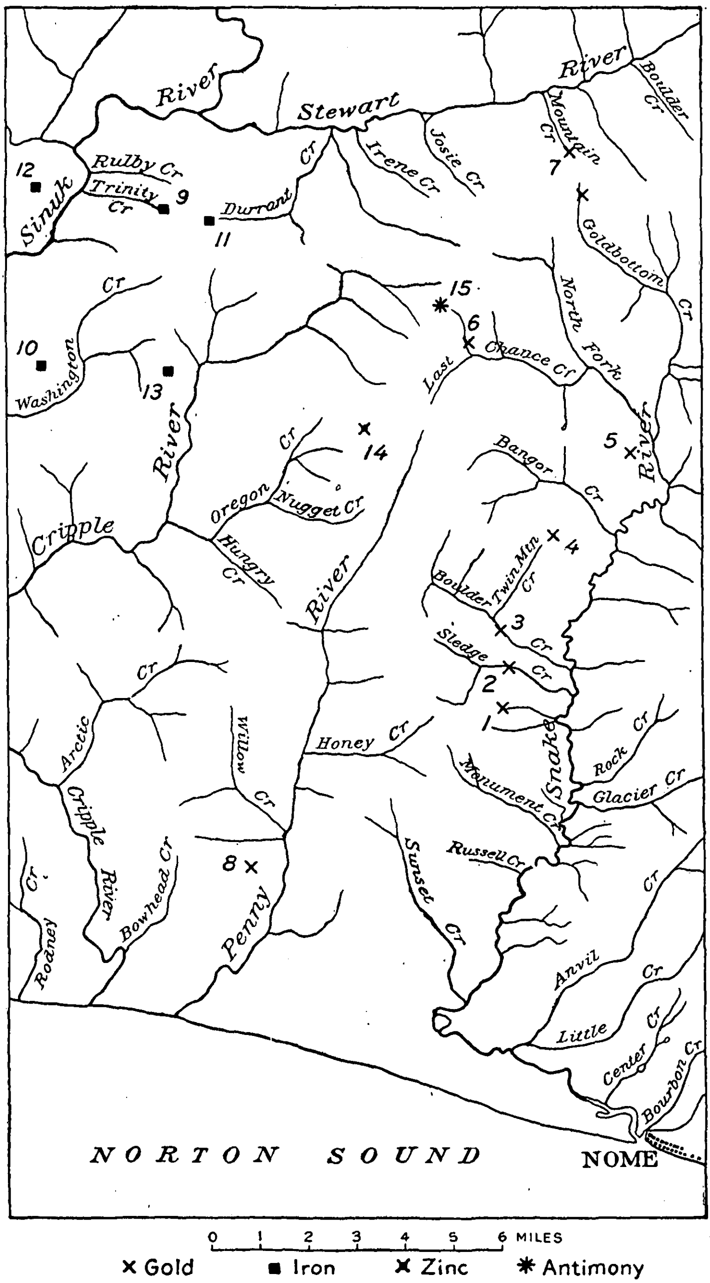

FIGURE 19.—Map showing location of metalliferous lodes northwest of Nome. 1, Alpha Creek; 2, Sledge Creek; 3, Boulder and Dakota; 4, Lilly; 5, Pioneer Gulch; 6, Waterfall Creek; 7, California; 8, Steiner; 9, Monarch; 10, Galena; 11, Mogul; 12, America; 13, Cub Bear; 14, 15, Christophosen.

The schist at the end of the drift strikes north and dips 45° W. A few quartz veins and several shear zones have been cut, but no definite lode has been encountered. The schist in places is highly mineralized and shows large cubes of pyrite. This material was said to be gold-bearing, but an assay made for the Geological Survey gave no returns for gold. Dust so covers the walls of the drift that little of the underground structure can be seen.

IRON DEPOSITS.

Several groups of claims have been staked for iron deposits in the upper basin of Cripple River and in the adjacent portion of Sinuk River basin. These are about 25 miles northwest of Nome (fig. 19). According to the reconnaissance surveys [82] the country rock of the region consists of schist, broken by belts of heavy limestone. The iron ore occurs chiefly in limestone areas. These deposits were first described by Eakin,[83] who made his examinations in 1914, soon after they were discovered. His work was supplemented by examinations made by Mertie[84] in 1916. Some additional notes were obtained by the writer in 1920. Eakin describes this general type of occurrence as follows:

> The iron-ore deposits consist of limonite veins and stockworks and their residual products. Hematite, galena, pyrolusite, and small quantities of gold also occur as accessories in some of the lodes. The examination was too brief to permit detailed studies, but the general impression gained is that there had been strong mineralization at certain localities, and that the mineralizing agencies had affected a considerable area.

The Monarch group of 15 claims appears to have had more development work done on it than on any of the others. Eakin states that this group covers a limestone ridge that trends eastward between Sinuk River and Washington Creek. He describes the deposit as follows:[85]

> It covers the ridge top for about 3,000 feet and extends laterally for over a mile. Within this property the ridge crest is broken by two gaps at an elevation of about 1,000 feet above sea level, in which are the chief deposits of iron ore. Elsewhere the limestone is more or less iron-stained and may contain small ore veinlets, but the average iron content of the limestone mass may be too low to permit its being classed as ore.
>
> The east gap is mantled by a heavy residual deposit of limonite and hematite, derived from the weathering of unusually abundant ore veins that cut the underlying limestones. The residual ores have also slumped down into the head of the gulch that leads northward from the gap, where they occur in considerable amounts. The veins in bedrock beneath the gap are apparently numerous and range in width from a

[82] Collier, A. J., and others, Gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, pl. 10, 1908.

[83] Eakin, H. M., Iron ore deposits near Nome: U. S. Geol. Survey Bull. 622, pp. 361-365, 1915.

[84] Mertie, J. B., jr., Lode mining and prospecting on Seward Peninsula: U. S. Geol. Survey 662, pp. 444-446, 1917.

[85] Op. cit., pp. 362-365.

few inches to about 30 feet. They are approximately vertical, but their persistence, either vertically or horizontally, is not determinable from the exposures.

In the west gap there is no important accumulation of residual ore. The underlying limestone is cut, however, by a wide stockwork of limonite and pyrolusite veinlets. No heavy veins were seen at this locality.

The residual deposits of the east gap have been developed over an area approximately 600 by 800 feet, in open cuts that range from a few yards to several hundred feet in length. A shallow shaft and a short drift have been driven into the deposit in the head of the northerly gulch, 50 feet below the gap level. An open cut at the south margin of the gap has uncovered a mass of undisturbed limonite, apparently a vein 30 feet in width, cutting the limestone country rock.

In the west gap several short open cuts have been made in loosened bedrock material which contains numerous veinlets of limonite and pyrolusite. Elsewhere on the claims the iron-stained limestone detritus has been thrown out of open cuts without revealing any high-grade ores.

The residual ore of the east gap has a loose granular texture and a high iron content, and is unusually free from injurious impurities. Two samples taken by the writer, one from an open cut at the east margin of the deposit and the other a composite sample from a line of open cuts 400 feet long across its center, were found to contain 53 and 55 per cent of metallic iron, respectively. The complete analysis of the composite sample, which is probably fairly representative of the whole deposit, is as follows:

Analysis of composite sample of iron ore from Monarch group of claims.

[Analyst, R. C. Wells, United States Geological Survey.]

SiO_2	5.53	TiO_2	None.
Al_2O_3	1.34	P_2O_5	.13
Fe_2O_3	78.30	S	Trace.
MgO	.10	MnO	1.37
CaO	1.97	BaO	Trace.
H_2O	10.40		
CO_2	1.10		100.24

The iron, manganese, phosphorus, and sulphur contents of the ore, calculated from this analysis, are as follows: Fe, 54.81; Mn, 1.06; P, 0.057; S, trace.

No samples were obtained from the veins from which this residual material has been derived. The character of the ores in the undisturbed veins was therefore not determined.

Only qualitative analyses of samples taken from the west gap were made. They contain limonite and pyrolusite in about equal amount. The veinlets appear to comprise only a small part of the general mass of the stockwork, so that the iron and manganese content of minable material is probably not high.

The development work done so far on the Monarch property has failed to furnish an adequate basis for estimating the quantity of ore available in either the residual deposits or the underlying veins. The size and extent of the veins for the most part can only be conjectured. The area of the residual deposits is fairly well outlined, but their depths have not been generally demonstrated. However, it seems certain that the residual high-grade ores aggregate at least several hundred thousand tons. Apparently they cover an area 600 by 800 feet to a depth of several feet. In places shafts 12 feet deep are said to have been sunk in ore. Although ore occurs in the head of the northerly gulch 50 feet or more below the level of the east gap, it is unsafe to assume that the divide is underlain by ore to this depth, for this ore is apparently not in place but has slumped down into the head of the gulch from the gap above. Obviously additional prospecting will be required to determine accurately the reserves of high-grade residual ores and to demonstrate the availability of the undisturbed vein ores. The stockwork of the west gap will also require careful investigation to determine its value. The relatively high manganese content of the veinlets and the reported association of gold with the manganese strengthens the possibility that this deposit may prove of commercial value.

The limestones on the property away from the gaps contain from 5 to 40 per cent of iron. The average content is probably nearer the lower figure, and if this proves true it seems doubtful that much of this material can be considered as commercial ore.

Mertie's interpretation of the facts available in regard to this ore body is in general accord with that of Eakin, but he has added some further details as follows:

The country rock is limestone, which has been brecciated and replaced by limonite. Hematite is present only as a subordinate constituent. A specimen of the ore taken from a trench at the head of Iron Creek shows on a polished surface massive limestone with numerous angular inclusions of iron-stained limestone, residual fragments of the shattered country rock. Pyrolusite, in places intergrown with calcite, is present in veinlets that cut the limonite and the replaced limestone. These relations and the probable genesis of this iron deposit will be discussed more fully in a later paper on the iron resources of Alaska. For this report it is sufficient to say that the iron ore now exposed on the ridge and in Iron Creek is a residual concentration, a surficial enrichment of an underlying lode. The iron content of this lode at depth can not be judged from the surface indications; in fact, it is entirely possible that this deposit is only a surface capping, or "iron hat," covering some other metalliferous deposit. The occurrence of galena and sphalerite with limonite in the Galena group near by, the presence of similar limonitic material in considerable amount in a silver-lead lode in the Inmachuk basin, and the constant association of limonitic material and other iron minerals with most of the gold lodes on the peninsula might be cited as evidence of this possibility.

Another group of claims has been described by Mertie [86] as follows:

The Galena group, consisting of nine claims, is about 2 miles southwest of the Monarch group on the divide between Sinuk River and Washington Creek. These claims, though prospected chiefly for their iron content, have also surface indications of both lead and zinc, in the form of galena and sphalerite.

It appears that the ore-bearing solutions have followed in large measure one or more of a system of joint planes in the country rock. On the Sunrise claim, one of this group, the country rock is crystalline limestone, the cleavage of which strikes east and dips 25° S. This limestone is cut by a number of joint planes, the more prominent of which had the following strikes and dips: N. 40° E., 65° NW.; N. 80° E., 70° N.; N. 15° W., 90°. Disseminated galena in a quartz gangue occurs along the vertical joint plane. This ore is said to show considerable values in gold.

An open cut on the Oso claim shows disseminated sphalerite, with a little pyrite, in the crystalline limestone. The extent of the zinc mineralization is not known. In a pit at another locality on the Oso claim the same system of jointing as above described was exposed, and vein quartz, with some iron-stained vein material, occurs along a joint plane striking N. 10° W. and dipping 75° N. Lilac-colored fluorite was also seen in this pit, but its exact relation to the mineralization could not be determined.

On the Fox and the Williams claims disseminated galena accompanied by quartz was observed in limestone and calcareous schist.

Considerable botryoidal limonite was seen on the dump at a prospect on the Kentucky claim.

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[86] Op. cit., p. 445.

The following description of the ore deposits of two groups of claims is taken from Eakin's report.[87]

The Mogul property consists of four claims situated on the Sinuk River and Washington Creek divide about 1½ miles east of the Monarch property. No development work has been done here, the locations being made on the strength of a few acres of the blossom of ore veins that cut the limestones locally. Evidence of the veins is found in heavily iron-stained limestone detritus that has a scant admixture of limonite nodules and vein fragments. There is little evidence as to the size and extent of the veins or the possibilities of commercial development.

The American group includes four claims situated at the base of a limestone ridge west of Sinuk River, below American Creek, 2 miles northwest of the Monarch property. The locations are said to cover an "iron-ore bed" over 50 acres in extent. The only development work done consists of a few pits 6 to 8 feet deep, and no analyses have been made of the ore. The locality was not visited by the writer.

The Cub Bear group of iron claims lies near the head of Cripple River on the divide between Cripple River and an eastern tributary of Washington Creek, at an elevation of about 1,000 feet. The developments consist of 12 trenches 20 to 30 feet long and 3 feet deep. The country rock is chiefly limestone, with a little interbedded schist. The mineralization occurred in a well-defined saddle between two knolls. The limestone of the eastern knoll strikes N. 10° E. and dips 15° E.; that of the western knoll strikes N. 10° E. and dips 20° W. Structurally the mineralization occurred along the crest of an anticline. The mineralized zone is exposed only by the trenches, as tundra covers the saddle. The trenches are alined about N. 5° E., which is approximately the strike of the country rock. Six openings are made on the north of the saddle, and six on the south. The trenches on the south expose limonite chiefly, with some hematite. The material is essentially iron-stained limestone, through which some small veinlets of iron oxide occur. The rock is badly fractured and seamed with incompletely filled veinlets of calcite. Only surface débris is exposed by the pits, and no rock of ore grade is seen on this side of the saddle. On the north side several of the trenches have exposed massive botryoidal limonite of good quality. A cellular limonite is also present on the dumps, and manganous oxide in small amount occurs with it. The quantity of ore on the dumps does not exceed a few tons. No ore in place is exposed.

The occurrence is very poorly exposed by the workings and elsewhere is covered by moss. Mertie reports sulphides to be present with the ore at the Mogul group of claims and suggests that the iron may merely be gossan material capping a sulphide vein. It is not possible to say whether this represents the gossan of a sulphide vein or not. No sulphide was seen. The zone of mineralization is probably 50 or 100 feet wide and, as observed, seems to occur along the shattered crest of a fold, which suggests that the iron oxide may be but a deposit resulting from the circulation of ground waters along this zone.

[87] Op. cit., pp. 364–365.

INDEX.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

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The maps whose price is stated are sold by the Geological Survey and not by the Superintendent of Documents. On an order amounting to $5 or more at the retail price a discount of 40 per cent is allowed.

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